Marking to Market versus Taking to Market

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Building on the idea that accounting matters for corporate governance, this paper studies the equilibrium interaction between the measurement rules that firms find privately optimal, firms' governance, and the liquidity in the secondary market for their assets. This equilibrium approach reveals an excessive use of market-value accounting: Corporate performance measures rely excessively on the information generated by other firms' asset sales and insufficiently on the realization of a firm's own capital gains. This dries up market liquidity and reduces the informativeness of price signals, thereby making it more costly for firms to overcome their agency problems.

Keywords: corporate governance, agency, accounting, gains trading, fair value.

JEL numbers: D82, M41, M52.

Introduction

Accounting statements are the primary source of verified information that firms provide to their stakeholders, and therefore an important ingredient of corporate governance. Accounting measurements are in particular explicit inputs in executive compensation contracts, debt covenants, and regulations such as prudential rules for financial institutions. They also play a more implicit

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but pervasive role in the enforcement of stakeholders' rights during events that are defining for corporations, such as takeovers, proxy contests, bankruptcy procedures, or rounds of venture-capital and private-equity financing.[1]

Amidst a global debate that has been raging for years,[2] accounting conventions have evolved from the use of historical costs towards "fair-value" measurements of assets and liabilities. The International Accounting Standard Board defines fair value as "the price that would be received to sell an asset or paid to transfer a liability in an orderly transaction between market participants at the measurement date."[3] This contrasts with historical-cost accounting whereby, broadly, balance-sheet items remain recorded at their entry value instead of reflecting all relevant data accruing from markets for similar items.[4]

The goal of this paper is to offer a framework for the study of accounting measures that builds on the primitive ingredients of information economics. We introduce accounting measurements as important corporate governance tools, and we determine the extent to which they should reflect market data. We are particularly interested in the mutual feedback between the design of privately optimal measurements by firms, and the efficiency of the secondary market for the items in their balance sheets.

Our starting point is a standard agency model of corporate finance in which the outside stakeholders of a firm need to provide inside stakeholders with incentives to figure out a value-maximizing strategy, which we simply model as the selection of a good project/asset. Insiders' rewards (prolonged employment, authorization to invest, managerial compensation,...) must be decided before the asset pays off, and must therefore be based on measurements of this payoff. Two such measurements are available to outsiders. They can avail themselves of a costless but noisy public signal from a market for similar assets. They can also obtain a costly measure of asset value by reselling the asset to imperfectly competitive informed buyers. We will say that the asset displays "latent capital gains" when the market signal is suggestive of a high payoff, and that a firm "realizes its latent capital gains" if the asset is resold at a high price. Uninformed and informed buyers make genuine bids for the asset; furthermore insiders have the ability to elicit fake bids that, unless executed, outsiders cannot distinguish from legitimate ones: the authenticity of the bids is unverifiable unless they are acted upon, i.e. generate a trade. Contingent on the public signal and the bids, the contract specifies whether to accept a bid, and if so, which one.

[1] Sloan (2001) surveys these implicit and explicit uses of accounting information in corporate governance and the related empirical evidence.

[2] See, e.g., Volker (2001).

[3] See International Financial Reporting Standard 13.

[4] Some depreciation and provisioning rules may take sufficiently negative market signals into account under historical-cost accounting. By contrast, mildly negative or positive market signals per se do not lead to a change in accounting value.

In the full-fledged equilibrium model, we solve for informed buyers' equilibrium bidding strategies, and endogenize the public market signal as publicly observable transactions by other firms seeking to resell comparable assets. An initial step in Section 2 by contrast takes the precision of the market signal and the distribution of bids for the asset as exogenous, and solves for the (privately) optimal contract.

This optimal contract has the following simple structure. If the market signal is above a threshold, then insiders get rewarded. If the signal is below this threshold, insiders are allowed to resell the asset above a given reserve price, and get rewarded if the sale is actually executed above this price. This abstract contract admits a realistic implementation, whereby insiders are rewarded if and only if a carefully designed accounting measurement of the project is above a threshold. The important feature of the measurement is its degree of conservatism. Under a more conservative regime, the accounting measure of the project (its "book value") increases more gradually following positive market data. In this sense the recognition of latent capital gains is more conservative. Insiders are therefore induced to realize their latent gains, i.e. take their asset to the market, more often in order to get rewarded. In the limit of a most conservative regime, only realized capital gains are recognized, as is the case under pure historical-cost accounting in practice.

Interestingly, this (privately) optimal contract trades off costs that closely mirror some of those mentioned by each side in the policy debate on fair-value accounting. Advocates of fair-value accounting have argued that historical-cost accounting induces distortions such as costly and unnecessary realizations of latent capital gains by firms. This practice of taking to the market assets that are booked below their resale values for no other purpose than increasing a firm's book value is referred to as "gains trading."[5] The opponents of fair value point at the irrelevant noise that market data may add to corporate performance measure.[6] Accordingly, our optimal contract (and accounting measure) minimizes the sum of two types of costs, those incurred when validating insiders' claims with an ex-post inefficient asset resale and the costs induced by the inefficient reward of insiders based on noisy market data absent such a resale ("reward for luck").

Section 3 then endogenizes the bids that firms receive for their projects. Firms can sell their assets to (a limited number of) informed buyers and (a large number of) uninformed buyers in a decentralized market. Buyers are randomly matched to firms. Without observing firms' contracts, nor how many fellow buyers are matched to a firm, they submit bids.[7] In equilibrium, firms adopt

[5] Exploiting the difference in accounting regimes between life and property US insurance companies, Ellul et al. (2015) find systematic evidence that historical-cost accounting induces "gains trading" in the insurance sector.

[6] Nissim and Penman (2008) collect quotes from more than 30 industry and regulatory reports on the costs and benefits of fair value. The most frequently mentioned costs are the irrelevant noise that it may add to accounting information and the difficulty to map public data into an objective "fair value" for important asset classes such as loans.

[7] We later allow firms to post contracts in order to lure buyers.

optimal contracts based on their beliefs about the distribution of bids for their assets, and buyers submit bids rationally anticipating such contracts. There can be two equilibrium degrees of liquidity in the market for assets. There exists a liquid, constrained-efficient equilibrium in which firms set high reserve prices when allowing resales, are conservative when updating their books upon positive market signals, and in which informed buyers bid aggressively so that resales are frequent. There may also exist an illiquid equilibrium in which firms rely too aggressively on market data, allow for asset resales too rarely at deeply discounted reserve prices, and in which informed buyers accordingly submit low bids. This illiquid equilibrium comes with higher agency costs for firms. It is unstable in the following sense. A regulation that forces firms to use (even a slightly) higher degree of conservatism than they find privately optimal when recognizing latent capital gains based on market data leads the constrained-efficient equilibrium to be the unique equilibrium.

We then relax the assumption that the agency contracts are secret, by positing instead that the sellers publicly post their reservation prices (à la Guerrieri et al 2010). Price posting eliminates the unstable equilibrium; in the unique equilibrium, though, the reservation price is smaller than that in the stable equilibrium under secret contracts as firms compete to attract buyers. The equilibrium involves higher agency costs.

Section 4 endogenizes the competitiveness of the asset market among informed buyers through a free-entry condition. It also endogenizes market signals as observed asset resales by other firms. When liquidity is endogenous, laissez-faire can no longer be constrained efficient. It leads to an excessive reliance on market data by firms in the form of an overly aggressive recognition of latent gains when measuring performance. The reason is that firms fail to internalize the effect of their accounting choices on the liquidity of the items that they seek to measure, where liquidity is defined both in terms of ease of trading and of the informativeness of price signals. Under laissez-faire, firms contract too much on transactions by other firms. They sell their own assets too rarely, and at deep discounts when they do so. Either a regulation that forces them to adopt more conservative accounting measures or the subsidization of liquidity addresses these informational externalities and reduces their agency costs. Taking to market is more efficient because asset resales occur at higher prices. So is marking to market because resale prices are more informative. The excessive use of fair value carries over to the case of public contracts (posted reservation prices). In the equilibrium with unobserved contracts, firms fail to internalize two positive liquidity externalities: more competitive resale markets and more informative market data. With posted contracts, firms internalize the former externality but still fail to do so with the latter.

Section IV summarizes extensions and robustness checks that are performed in an online appendix. Section V provides further discussion and discusses alleys for future research.

Related Literature

This paper relates to the burgeoning accounting literature on the real effects of accounting regimes. Marinovic (2017) in particular studies the effect of the measurement regime applied to an asset on the outcome of an auction for that asset.[8] We extend this literature by developing a full-fledged economic theory of optimal accounting measures. In our framework, both corporate governance mechanisms, including measurement regimes, and liquidity in the markets for balance-sheet items are the endogenous outcome of equilibrium optimizing behaviors by all agents.

The three sections of the paper each relate to different literatures. Section 2 that derives firms' privately optimal contracts is most related to the agency literature on informativeness of performance measurement. Holmström (1979) proves that incentives should be based solely on a sufficient statistic of unobservable effort. Kim (1995) shows that information systems are ranked if the likelihood ratio distribution of an action choice under an information system is a mean-preserving spread of the likelihood ratio distribution under the other. Section 2 derives the optimal mix between using a free, but noisy external signal and using a costly, but more precise one obtained through resale. The paper shares with the literature on costly state verification initiated by Townsend (1979) and with the "variance-investigation" literature in accounting the idea that the optimal agency contract uses costly inspections so as to verify the agent's claim. Whereas negative reports lead to verification in this literature, positive reports do in our setup. Dye (1986) studies a principal-agent model in which the principal faces the related problem of optimally combining two sources of information, the agent's output and a direct but costly verification of her effort level. Our paper interprets the "verification cost" as a discount on an asset resale, and to the best of our knowledge, is the first to derive marking to market and gains trading as optimal features of an optimized information system.

Section 3 endogenizes resale costs by positing a matching process and a first-price auction among bidders. The reserve price is first assumed to be secret as in Elyakime et al (1994), in which the number of bidders is unlike here known.[9] The key new feature relative to the auctions literature is that the seller does not have a set valuation. Rather, the reserve price is derived from a contracting problem, where the transaction cost of selling the asset is compared with the imprecision of the market signal and both jointly contribute to set the agent's incentives.

Like the literature on auctions with an endogenous number of bidders (e.g. Levin-Smith 1994, Jehiel-Lamy 2015b), Section 4 endogenizes entry through a zero expected profit condition. And

[8]Other contributions include Allen-Carletti (2008), Bleck-Gao (2012), Bleck-Liu (2007), Heaton et al. (2010), Laux-Leuz (2010), Otto-Volpin (2015), and Plantin et al. (2008).

[9]In their framework, Elyakime et al. prove that the seller would be individually strictly better off if he could commit to a reserve price. The same would hold in our framework as well if sellers were monopolists. Jehiel and Lamy (2015a) endogenize secret reserve prices through heterogeneous seller valuations.

the seller benefits from a liquid market.[10] The novelty is that liquidity depends on the accounting choices made by the other firms. This externality is at the core of our welfare analysis.

One can also draw an interesting analogy with the literature on thick-market externalities (Admati-Pfleiderer 1988, Pagano 1989). In that literature, investors with liquidity needs who are able to select their trading date prefer to bunch with other liquidity traders as this limits the ability of informed buyers to exploit mispricing and further may induce more competition among informed buyers. A common feature with our paper is that sellers' decisions (when to trade, extent of fair-value accounting) affect the welfare of other sellers through the impact on informed trading. For instance, Admati and Pfleiderer endogenize information acquisition through a free-entry condition and show that the patterns of trading volume that exist in the model with a fixed number of informed traders become more pronounced if the number of informed traders is endogenous. Besides the obvious differences in focus (intraday trading volatility vs. accounting choices) and modelling (our model captures the decision of whether to bring the asset to the market rather than the choice of when or where to bring it to the market), our paper emphasizes the benefit (performance measurement), rather than the cost of informed trading.

I. Marking to market versus taking to market: Optimal contract

A. Model

There are three dates $0, 1, 2$. There are two parties, a principal and an agent, involved in a project—a "firm"—that is initiated at date 0 and pays off at date 2. The principal stands for outsiders—the constituencies that have a stake in the firm but do not operate its assets, such as diffuse shareholders, arm's length creditors, or a prudential supervisor in the case of financial institutions. The agent stands for insiders—the stakeholders who run the firm or closely oversee its operations, such as controlling blockholders, directors, or top managers.

The principal does not discount time and is risk neutral over consumption at each date. The cashless agent derives utility at dates 0 and 1 only. The principal can provide the agent with any

[10] In Aghion et al (2004), the firm elicits buyer interest in the asset (which is also sold for performance measurement purposes) by forcing passive shareholders to tender their shares (drag-along institution). Here liquidity is not driven by an internal design, but by accounting choices made by other firms. Asriyan et al (2017) study a timing game between two privately informed sellers of assets with correlated values. In their world of adverse selection, an early resale generates a (positive or negative) externality on the holdout seller. Multiple equilibria may coexist. Their paper, of which strategic timing of sales is the essence, shares with ours the idea that taking to market involves externalities, but these externalities have a different nature and also are unrelated to accounting measurement.

utility level $u \in [0,1]$ at date 1 at a monetary cost u.[11] The important feature is that the agent's utility cannot be costlessly backloaded to date 2, so that date-1 measurements of the final cash flow matter for performance evaluation.[12]

This date-1 utility transfer from the principal to the agent lends itself to three standard interpretations that we will use when discussing the practical implications of the optimal contract for accounting measures:

- *Interpretation: (1) Continuation/expansion versus liquidation/downsizing.* Under this interpretation, the principal may entrust the agent with a new project, or with the continuation of the current one (as opposed to liquidation) at date 1. The agent derives a private benefit from this new project or from continuation (normalized to 1), but the project value net of this private benefit is negative (normalized to -1).

- *Interpretation: (2) Transfer of corporate control.* Under this interpretation, a new principal may take control over the company and implement a strategy that yields the incumbent investors a gain (normalized to 1) and costs a private benefit to the agent (normalized to -1). For example, the new principal may be a value-enhancing raider, who, to implement his strategy (worth 1 to investors), will fire the agent at date 1, thereby costing the latter the private benefit (1) from remaining involved with the firm. Alternatively, control may be transferred to creditors (or a prudential supervisor) who may impose a conservative strategy that the agent dislikes.[13]

- *Interpretation: (3) Managerial compensation.* Finally, the transfer may correspond to managerial compensation. The assumed date-1 utility $u \in [0,1]$ captures risk-aversion in the simplest fashion.[14]

Project selection. The agent must select a project or asset at date 0. Projects may be of two types, 1 or 2. Both types require the same date-0 investment outlay. There are two possible states at date 2, one state in which type-1 projects pay off h whereas type-2 projects deliver l, where $h > l$, and another state in which project types swap these payoffs. The principal and the agent have the

[11] Setting the cost of transferring utility u at u is just a normalization given our welfare criterion below. Section IV introduces alternative costs of utility transfers when discussing alternative welfare criteria.

[12] Section IV discusses the more general case in which the agent discounts date-2 utility at a higher rate than the principal.

[13] Unlike in the case of a raider, the gain for the principal is an ex-ante one (as in Dewatripont-Tirole 1994, in which a transfer of control to debtholders—optimally when performance measures are unfavorable—credibly leads to a conservative strategy and disciplines management).

[14] It amounts to assume that the manager's date-1 utility over consumption c_1 is equal to $-\infty$ for $c_1 < 0$, to c_1 for $c_1 \in [0,1]$, and to 1 for $c_1 \geq 1$.

common prior that a payoff of h is associated with the type-1 project with probability $1/2$. The principal observes the type of the project selected by the agent.[15]

At date 0, before selecting a project, the agent receives a private signal that allows him to refine his forecast of the date-2 state. The signal's precision depends on an effort level secretly chosen by the agent. If the agent "behaves," the signal matches the state with probability p. If he "shirks," the signal is correct with probability $p - \Delta p$ only, where

$$\frac{1}{2} \leq p - \Delta p < p < 1.$$

By shirking, the agent derives a private benefit added to any utility he may receive from the principal and that we denote $B > 0$.

In other words, the principal-agent relationship is plagued by a moral-hazard problem that takes the form of a nonobservable forecasting effort exerted by the agent. This effort stands for any time and resources that insiders devote to figuring out the strategy that generates the highest firm value instead of devoting them to tasks that they find more rewarding. Depending on the context, such strategic decisions encompass asset allocation, market entry or exit, risk-management decisions, etc...This incentive problem creates a role for performance-based contracts. We suppose that:

$$\beta \equiv \frac{B}{\Delta p} \leq 1.$$

This means that if the principal observed the date-2 payoff y at date 1, he could elicit effort by granting the agent utility $B/\Delta p$ whenever $y = h$ and 0 when $y = l$.[16] In this second-best case, in which the principal-agent relationship is plagued only by a moral-hazard problem but not by a measurement problem, the expected cost for the principal to induce the agent to behave would be $p\beta$.

We are interested in assessing the additional costs induced by the measurement problem due to the fact that neither the principal nor the agent observe the project payoff before date 2.[17] The principal has access to two measurements of the project's payoff at date 1: a public signal and resale opportunities.

Measurement: (1) Public signal. First, a public signal $s \in \mathbb{R}$ is available at date 1. The distribution of this signal conditional on a final payoff $y \in \{h; l\}$ admits a strictly positive differentiable density $f_y(s)$ such that f_h/f_l is strictly increasing. For brevity, we will rule out some corner solutions by assuming that the signal can be arbitrarily informative and so $f_h(s)/f_l(s)$ spans $(0, +\infty)$ as s spans $\mathbb{R}$. We denote by F_y the conditional c.d.f. of the signal.

[15]This is immaterial until Section III.

[16]Recall the the date-1 utility of the agent is bounded above by 1.

[17]The analysis is unchanged if the agent privately observes the payoff at date 1.

We interpret this abstract date-1 signal as publicly observable transaction data for assets that are comparable to that chosen by the agent. This interpretation corresponds to the way we endogenize the signal in Section III. For notational simplicity, we assume that this signal is freely available. In practice, external pricing services or assessment of fair values may create a cost of obtaining this signal. The qualitative results however would not be affected by the introduction of a cost of observation.

Measurement: (2) Resale opportunities. The second source of information available to the principal are resales of the project to informed buyers at date 1. We introduce imperfectly competitive bidding in the date-1 market for projects as follows. Buyers make (public) bids for the firm's asset; because the asset is always worth at least l, there is a perfectly elastic supply of bids by uninformed bidders at any price less than or equal to l; buyers may also possibly make bids above l (see below). Those genuine bids by serious outside buyers will deliver the offered price if they are selected by the firm. Beyond the genuine bids, the agent has the ability to manufacture (or have manufactured) fake bids that, unless they are executed, the principal cannot distinguish from the genuine ones. The agent reports a set of bids, a superset of genuine bids.[18] Contingent on the public signal s and the reported bids, the contract specifies whether to accept a reported bid, and if so which one.[19]

As already observed, regardless of the project's payoff, the firm always faces a perfectly elastic supply of bids at or below l. We make assumptions on the distribution of genuine bids strictly above l, that later will be consistent with optimal bidding by the matched informed buyers. First, a project that pays off l elicits no such bids. Neither does a h-project, with probability q_0 (q_0 will be the probability that no informed buyer shows up). With probability $1 - q_0$, a project that pays off h elicits a finite number of bids that take values in $[r_-, r_+]$, where $r_- > l$ and $r_+ \leq h$. Overall, this implies that bids below or equal to l are uninformative whereas any bid within $[r_-, r_+]$ perfectly reveals a high payoff to the agent. This distribution of bids will result later from the assumption that the firm is matched to a large number of uninformed buyers and, with probability $1 - q_0$, to one or more perfectly informed ones. This assumption clearly simplifies the characterization of the optimal contract, which in turn makes the characterization of equilibria in Sections 3 and 4

[18]Here the agent cannot conceal genuine bids (the motivation being that the buyers can send a copy of the offers to the principal). This assumption is irrelevant, though. The ability for the agent to conceal bids can only worsen the agency problem; however the analysis below applies verbatim to the case of bids that are privately observed by the agent. Intuitively, the agent will not want to conceal high bids, and low bids are irrelevant, as they do not lead to rewarding the agent, so their being concealed does not matter.

[19]Assuming away partial asset sales is for simplicity. The difficulty attached to selling a small fraction of the asset to obtain information about its real value without incurring the cost is known from other literatures, e.g., those on transfer pricing, labor economics, and venture capital. In our equilibrium model with posted contracts (see Sections B.1 and III), a small fraction for sale would not attract buyer interest. But even without price posting (as is assumed here), buyers matched with a seller would try to rematch with another seller if they observed that little profit is to be made because little is for sale (in our model, matched buyers have no incentive to change their match, even at no cost).

particularly tractable.[20] More technically, we assume that (as will be the case in equilibrium) bids and the public signal are independently drawn, and that H, the c.d.f. of the highest bid received by a firm that has a h-payoff project, has full support and is differentiable over $[r_-, r_+]$ (and such that $H(x) = q_0$ for $l \leq x \leq r_-$ and $H(x) = 0$ for $x < l$).

Section II, which endogenizes bids, defines "high-winner-curse" equilibria as equilibria in which, as is assumed in this partial-equilibrium section, the distribution of the highest informed bid H is not contingent on the signal s. Intuitively, informed bidders know $y = h$ and are therefore unaffected by the public signal s. In a high-winner-curse equilibrium, informed bidders compete with each other but not with the uninformed, who are too concerned about the winner's curse to bid at their level. We will show that all equilibria are high-winner-curse provided l is sufficiently small (i.e., adverse selection is strong). We will also see that if this is not the case (low-winner-curse equilibria), r_- must increase with s, and strictly so beyond some threshold signal (and so must H stochastically), so that uninformed bidders again do not find it profitable to bid above l.

Efficiency criterion. Our efficiency criterion throughout the paper is to maximize the total expected cash flows from a project that accrue to outsiders (principal). In the online appendix, we show that the insights carry over to alternative criteria. First, even if the principal owns the project, the social welfare function may put weight on the agent's welfare. Second, the agent may own the project but need to finance the investment from a competitive capital market. In either case the objective function—that of the social planner in the first case, and that of the agent in the second—is a convex combination of the cost of resale at discounted prices and utility transfers to the agent, and the results derived in the paper generalize.

We suppose that the parameters are such that a project creates value for the principal only if the agent behaves. In this case, satisfying our criterion amounts to minimizing the total agency cost—expected transfer to the agent and expected resale cost—that the principal must incur in order to induce the agent to behave.

Summary of timing. Figure 1 summarizes the sequence of events:

[20]See Section IV for an extension with imperfectly informed buyers. Then bids may not be perfectly informative, but the analysis carries through nonetheless.

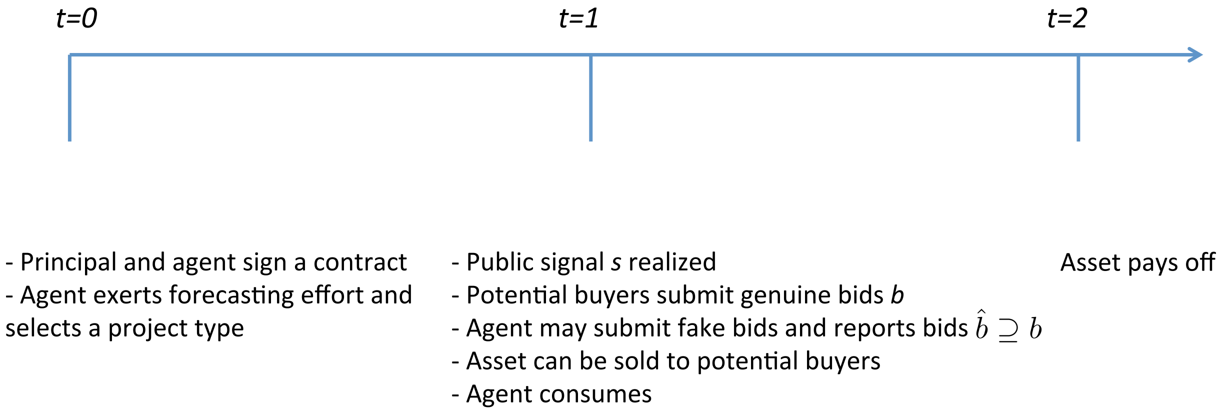

Figure 1. Timeline.

B. Optimal contract

Assuming that the principal can fully commit to a contract, we solve for the contract that minimizes the cost to the principal from inducing the agent to behave.[21] Because the principal at date 1 only has access to measures of the terminal payoff, he writes a contract that specifies how each measure (signal and resale) is used to determine the compensation of the agent. A general mechanism is such that after the signal s is realized, and bids are solicited, the principal makes resale and compensation decisions that depend on the signal, the bids he observes, and (for the compensation decision and if the asset is sold) the resale price.[22] We let:

(1) $$\overline{\beta} \equiv \sup_s \{F_l(s) - q_0 F_h(s)\}.$$

The following proposition shows that the optimal contract has a simple structure.

Proposition 1. ***(Optimal contract)*** *If $\beta > \overline{\beta}$, the firm cannot elicit high effort. If $\beta \leq \overline{\beta}$, in a high-winner-curse equilibrium ($H$is independent of s), the optimal contract is characterized by a threshold σ and a reserve price $r \in [r_-, r_+]$ such that:*

- *if the signal is above σ, then the agent receives utility 1;*

[21]For brevity, we suppose that the participation constraints of the principal and the agent are always satisfied under this contract; the analysis is qualitatively unchanged is they are binding (see online appendix E.4 for the case of an agent securing financing from a competitive financial market).

[22]We impose no restriction on feasible mechanisms, and allow in particular for stochastic ones.

- *if the signal is below σ, then the asset is sold if and only if it receives a bid at or above the reserve price r, and the agent receives utility 1 if the sale is executed;*

- *the agent receives zero utility otherwise.*

The agency costs at the optimal contract are

$$p\beta + 1 - F_l(\sigma) + pF_h(\sigma) \int_r^h (h-t)dH(t). \tag{2}$$

Proof. See the appendix. ∎

We assume that $\beta \leq \overline{\beta}$ for the rest of the paper. The optimal contract rewards the agent if the signal is above a cut-off σ, or if it is below this cut-off and the agent is able to demonstrate a high value by reselling the asset above a reservation price r. The determination of the parameters (σ, r) that characterize the optimal contract is instructive. It amounts to finding (σ, r) such that the agency costs are minimized subject to incentive-compatibility:

$$\min_{\{\sigma,r\}} \left\{ (1-p)(1-F_l(\sigma)) + p(1-F_h(\sigma)) + pF_h(\sigma) \left[1 - H(r) + \int_r^h (h-t)dH(t) \right] \right\} \tag{3}$$

s.t.

$$F_l(\sigma) - H(r)F_h(\sigma) = \beta, \tag{4}$$

$$r_- \leq r \leq r_+. \tag{5}$$

The restriction that the reserve price lies in the support of bids (5) is without loss of generality. The incentive-compatibility constraint (4) is derived as follows. Effort raises the probability of a payoff h by Δp at the cost of the private benefit B. An h payoff raises in turn the agent's expected utility due to favorable signal realizations by $(1 - F_h(\sigma)) - (1 - F_l(\sigma)) = F_l(\sigma) - F_h(\sigma)$ and due to asset resales by $[1 - H(r)]F_h(\sigma)$. Injecting (4) in (3) yields expression (2) for agency costs. Each of the three terms in (2) admits a simple interpretation. The first term $p\beta$ is the second-best cost that would prevail absent measurement frictions. The two other terms represent the cost of the measurement frictions that we added to this standard agency problem. The second term, $1 - F_l(\sigma)$, is the cost from rewarding the agent for luck when mistakenly using the public signal, whereas the last term, $pF_h(\sigma) \int_r^h (h-t)dH(t)$, represents the expected transaction cost from sales. The optimal contract trades off these latter two costs.

Ignoring constraint (5), the first-order condition for this program reads:

$$\frac{f_h(\sigma)}{f_l(\sigma)} = \frac{p(h-r)+1}{p\int_r^h H(t)dt}. \tag{6}$$

Condition (6) states that at (σ, r), the marginal cost of rewarding the agent based on good signals ("marking to market") is equal to that of rewards based on successful resales ("taking to market"). We show in the proof of Proposition 1 that $\{(4); (6)\}$ admits at most one feasible solution (σ, r). If there is one solution, it characterizes the optimal contract.[23]

If $\{(4); (6)\}$ admits no solution, the optimal contract is a corner solution ((6) is slack) such that when the signal is below σ, either there are no resales ($H(r) = 1$), or the asset is sold at any price above r_- ($H(r) = q_0$). When endogenizing bids in Section II, we refine away equilibria with such corner contracts (that we detail in the proof of Proposition 1).

C. Implementation with an accounting measure

The abstract optimal contract (σ, r) admits a simple and realistic implementation that builds on an appropriate accounting measure of the project. We generally define an accounting measure as a date-1 valuation of the project equal to:

- the resale proceeds if the project was resold at date 1;
- a value $m(s)$ otherwise, where $m(.)$ is strictly increasing in the public signal s.

Such a generally defined accounting measure has the realistic properties that cash-on-hand at date 1 is booked at face value, and that the only input used to value the future cash flow absent a resale is public information s.

Suppose that such an accounting measure satisfies in addition $m(\sigma) = r$. A mechanism that transfers utility to the agent from the principal if and only if the book value of the firm is larger than r at date 1 implements the optimal contract. This is because the book value is above r if market news is such that $s \geq \sigma$, or if $s < \sigma$ and the agent successfully sells the project at a price above r. Under this implementation, there is no explicit contracting on resales. The accounting measure induces insiders to realize latent gains optimally.

Construction of an optimal accounting measure. We now explicitly construct such an accounting measure that implements the optimal contract as follows. We start from the verbatim official definition of a fair-value measurement as "the price that would be received to sell an asset at the measurement date." In line with this definition, we build a measure based on a market-consistent estimate of the resale value of the asset at date 1.

Formally, after observing a market signal s at date 1, an econometrician infers that the price that the project would fetch were it taken to the market exceeds $x > l$ with a probability $D_s(x)$

[23] We show in the online appendix that the second-order condition for a minimum is globally satisfied.

that satisfies

$$D_s(x) = \frac{pf_h(s)(1 - H(x))}{pf_h(s) + (1-p)f_l(s)}. \tag{7}$$

For every $\alpha \in (0,1)$, we define the accounting measure $m_\alpha(s)$ as the lowest value that the realized resale price would exceed with probability at most α were the project taken to market at date 1. Formally, for every signal realization s:

$$m_\alpha(s) = \inf\{x > l \mid D_s(x) < \alpha\}. \tag{8}$$

The value $m_\alpha(s)$ is increasing in s and decreasing in α. One can therefore interpret α as the *degree of conservatism* of the accounting measure $m_\alpha(s)$ because it quantifies the extent to which the measure $m_\alpha(s)$ recognizes the possible latent gains on the project suggested by signal realization s. For $\alpha \geq 1 - q_0$, $m_\alpha(s) = l$ for all s. This is akin to historical-cost accounting as only realized gains affect corporate governance. Conversely, as α becomes arbitrarily small, the measure is very aggressive in that it books the project at a value close to the upper bound of the support of H unless the realization of s is very small.

Proposition 2. ***(Optimal degree of conservatism)*** *The optimal contract (σ, r) can be implemented using an accounting measure $m_\alpha(s)$ with degree of conservatism α such that*

$$\alpha = \frac{pf_h(\sigma)[1 - H(r)]}{pf_h(\sigma) + (1-p)f_l(\sigma)}. \tag{9}$$

Proof. The optimal contract (σ, r) is implemented with a degree of conservatism α such that $m_\alpha(\sigma) = r$. Injecting this condition in (8) yields (9). ■

Relation to fair value hierarchy. The International Financial Reporting Standard 13 that defines fair value uses a "fair value hierarchy" that classifies balance-sheet items according to the nature of the inputs required to determine their fair value. Level 1 items are those valued using only "quoted prices in active markets for identical assets or liabilities that the entity can access at the measurement date." Conversely, level 2 and 3 items cannot be directly marked to market based on listed prices this way, and are rather "marked to model." Their fair value is based on a valuation model, and as such it involves assumptions (e.g., absence of arbitrage opportunities or complete markets) and the use of proprietary information.

This hierarchy is a coarse characterization of the ease with which one can identify the price at which an item would trade at the measurement date. In our setup, this concept of liquidity evolves continuously as the public signal becomes more accurate and the informed bids less dispersed. Ideally, a level-1 signal would be generated by publicly observed transactions for assets identical to that of the firm provided these assets face a perfectly elastic demand. This is of course an abstraction. Even liquid assets usually exhibit a bid-ask spread. Furthermore, the lag between measurement and disclosure by itself introduces noise as assets fundamentals and prices fluctuate over time.

Practical interpretations. It is worthwhile noting that this implementation of the optimal contract resembles arrangements that prevail in practice in the three interpretations of the model mentioned earlier:

- *Continuation/expansion versus liquidation/downsizing.* Through covenants with creditors or prudential requirements, accounting measures may determine the level of cash flow available for new investment or conversely the size of downsizing. In either case the management may be affected by the resulting policies. Accounting measures may also have an impact through the allocation of control rights between the venture capitalist and start-up management. Last, a poor accounting performance may jeopardize the manager's tenure at the helm of the firm.

- *Transfer of corporate control.* The mechanism can be interpreted in this case as a transfer of control rights from shareholders (the agent) to creditors (the principal) following the breach of a debt covenant stipulating that the book value of the firm be above the threshold r. Shareholders continue/expand the firm if they remain in control whereas creditors liquidate or downsize it otherwise. As in Dewatripont-Tirole (1994), one can endogenize the respective payoffs of creditors and shareholders from each course of action as resulting from the respective curvatures of their claims.[24] This mechanism can also be interpreted as a stylized representation of prudential regulation in the particular case in which the creditors are the depositors of a bank or the policyholders of an insurance company. Under an alternative control transfer interpretation, the mechanism describes conflicts of interests between diffuse and large shareholders, whereby the former are more likely to tender their shares in a hostile takeover if the incumbent insiders fail to meet some objectives in terms of firm book value. Note that this role of accounting measures in the market for corporate control is implicit in practice, rather than resulting from explicit contracts. Sloan (2001) surveys the various channels through which accounting measures play an important implicit role in corporate governance.

- *Managerial compensation.* In this case the optimal mechanism admits a straightforward interpretation as a performance-based bonus.

The remainder of the paper endogenizes the environment facing each firm. We are interested in particular in studying whether the degree of conservatism that each firm finds privately optimal is also socially optimal, i.e., minimizes firms' agency costs.

[24]Creditors who have a concave payoff favor the risk reduction associated with liquidation/downsizing whereas shareholders with their convex claims (and managers) favor continuation/expansion.

II. Short-term equilibrium

This section endogenizes the bids received at date 1 as resulting from the interaction of many firms and potential buyers in a decentralized market. Suppose there are a continuum of firms with unit mass. Each faces the same situation as that described in the previous section. The project type chosen by a firm is not observed by other firms. Each firm receives a signal about its project payoff at date 1 whose conditional distributions $F_h,\ F_l$ are identical across firms and have the same properties as in the previous section. In this section, the joint distribution of the signals is immaterial.[25]

The economy is also populated by a continuum of informed buyers with mass λ who are risk-neutral over consumption.[26] Firms can sell their assets to the informed buyers in a decentralized market at date 1. Firms and buyers interact as follows. Each buyer is randomly matched to a firm and privately observes the payoff from its project.[27] Without observing the firm's contract,[28] nor how many fellow buyers are matched with this firm, he submits a bid. The matching technology is such that each firm is matched with k informed buyers with probability q_k.

A well-known and natural random matching process is urn-ball, whereby buyers are uniformly and independently distributed across firms. With a unit mass of firms and a mass λ of buyers, this yields a distribution of buyers per firm $\{q_k(\lambda)\}_{k\in\mathbb{N}}$ such that for all k

$$q_k(\lambda) = \frac{\lambda^k e^{-\lambda}}{k!}. \tag{10}$$

We will adopt this particular specification in Sections B and III in which λ is not fixed. The following Section A characterizes the equilibrium assuming only

$$0 < q_0 < q_0 + q_1 < 1. \tag{11}$$

Finally, there are also an arbitrarily large mass of uninformed buyers matched to firms. They submit bids based only on their observation of the firm's public signal.[29]

A. Equilibrium

In equilibrium, firms write optimal contracts given correct beliefs about bidders' strategies, and each bidder bids optimally given correct beliefs about firms' contracts and other bidders' strategies.

[25] Public signals are still exogenous in this Section. Section III will endogenize them and thus their joint distribution as noisy observations of asset resales.

[26] Section B.2 tackles the case in which λ is uncertain at the contracting date. Section III endogenizes λ with a free-entry condition.

[27] That each buyer meets with one firm is only a normalization.

[28] Section B.1 tackles the case in which firms post contracts.

[29] The public signal is uninformative about the project's payoff for informed buyers since they perfectly observe it.

We restrict the analysis in two ways. First, we look at equilibria in which uninformed bidders find bids above l suboptimal and do not make such bids. Second, this model in general exhibits bootstrap equilibria, in which the bidders bid high because the firm sets a high reservation price and the firm sets a high reservation price simply because there are no lower bids, even though the firm would be willing to accept lower bids if they existed. We will refine away such unnatural equilibria using a simple adaptation of the Intuitive Criterion to our context. Informally, an out-of-equilibrium offer $t = r - \epsilon$ (for ϵ small) may be turned down because it generates sufficiently pessimistic beliefs for the firm (the offer for instance is interpreted as coming from an uninformed bidder or, worse still, from an informed bidder knowing that $y = l$). Suppose, however, that given equilibrium strategies an uninformed bidder (and a fortiori an informed bidder with bad news) makes a strictly negative profit when bidding $t = r - \epsilon$ if this offer is accepted with strictly positive probability. By contrast, an informed bidder with good news makes a profit that is higher than his equilibrium profit if offer $t = r - \epsilon$ is accepted by the firm. The Intuitive Criterion then states that the firm should interprete offer $t = r - \epsilon$ as coming from an informed bidder with good news, and therefore accept it if condition (6) is slack. The Intuitive Criterion therefore rules out the bootstrap equilibria described above and (6) indeed obtains in equilibrium.

We define a "high-winner-curse" equilibrium as an equilibrium such that the distribution of informed bids does not depend on the signal s conditionally on the project type. We will show that if l is sufficiently small other things being equal, the set of equilibria is comprised of either one or two high-winner-curse equilibria. We here content ourselves with the broad lines of the argument: See the proof of Lemma 3 in the appendix for technical details.

Definition. ***(Equilibrium)*** *A high-winner-curse equilibrium is a strategy $\{\sigma, r\}$ for the firm and bidding strategies for the uninformed and informed bidders, such that*

1. *Uninformed bidders (and a fortiori informed bidders with bad news) optimally never bid above l.*

2. *Informed bidders with good news optimally bid in a state-independent way with support $[r_-, r_+]$ satisfying $l < r_- \leq r_+ \leq h$, generating a c.d.f. $H(t)$ for the highest bid.*

3. *The contract $\{\sigma, r\}$ is optimal for the firm given bidding strategies.*

4. *The equilibrium satisfies the Intuitive Criterion.*

A low-winner-curse equilibrium satisfies the same conditions except that bids are non-trivially state-contingent (with support $[r_-(s), r_+(s)]$ and c.d.f. of the highest bid $H(t, s)$) and so is the reserve price $r(s)$.

Suppose first that a given equilibrium is high-winner-curse. This has the following implications for informed buyers' strategies and firms' contracting decisions.

Informed bidding strategies. We show in the proof of Lemma 3 that for a high-winner-curse equilibrium, the distribution according to which informed buyers mix their bids for an h-project, S, is either a Dirac delta at h, or satisfies the properties assumed in Section I. We fully address the former, degenerate case (which will be ruled out in Section III, as bidders would make no profit) in the proof of Lemma 3, and focus here on the latter situation, which implies that firms' contract (σ, r) is characterized by Proposition 1.

We show in the proof of Lemma 3 that the lower bound of the support of S, r_-, must in equilibrium be equal to the bidders' (correct) expectation of r.[30] This latter property has the key implication that the equilibrium probability that the sale of a good project fails to go through depends only on the absence of an informed buyer due to random matching. Thus it must be that in equilibrium, the probability of resale of an asset taken to market is $1 - q_0$, or $H(r) = q_0$. This implies that the incentive-compatibility constraint (4) reads in equilibrium:

$$F_l(\sigma) - q_0 F_h(\sigma) = \beta. \tag{12}$$

Each firm then faces a highest-bid distribution H such that for all $t \geq l$,

$$H(t) = \sum_{k \geq 0} q_k S^k(t).$$

The expected resale cost is given by the informed buyers' profit, which can be computed by looking at the lowest bid, r, in the support of optimal bids. This lowest bid is a winning one only if there are no other buyers, and so the expected resale cost is equal to

$$pF_h(\sigma) \int_r^h (h-t)dH(t) = \frac{\lambda p F_h(\sigma) q_1 (h-r)}{1-q_0}. \tag{13}$$

Optimal contracts. We have seen that optimal bidding requires that the optimal contract (σ, r) must be such that $r = r_-$ and that σ is a solution to (12). Furthermore, from Section I, it must either satisfy

$$\frac{f_h(\sigma)}{f_l(\sigma)} = \frac{p(h-r)+1}{p\int_r^h H(t)dt}, \tag{14}$$

which from (13) can be rewritten

$$\frac{f_h(\sigma) q_0}{f_l(\sigma)} = \frac{1 + \frac{1}{p(h-r)}}{1 + \frac{\lambda q_1}{q_0(1-q_0)}}, \tag{15}$$

[30] The distribution S is determined by the conditions $(h-t)\sum_{k\geq 1} q_k S^{k-1}(t) = q_1(h-r)$ for all $t \in [r, r_+]$ and $h - r_+ = q_1(h-r)/(1-q_0)$.

or be a corner contract such that $r = r_-$ and (15) is slack. The proof of Lemma 3 shows that such equilibria with corner contracts do not survive the Intuitive Criterion.

Reciprocally, we show in the proof of Lemma 3 that any (σ, r) that satisfies (12) and (15) corresponds to a high-winner-curse equilibrium if l is sufficiently small other things being equal, and furthermore that all the equilibria that we consider are actually high-winner-curse in this case. The condition that l be sufficiently small ensures that for any pair (σ, r) that solves (12) and (15), uninformed bidders do not find it profitable to bid at or above r in the corresponding equilibrium even for the best signal triggering a sale ($s = \sigma$). A sufficient condition for this is that such a bid loses money even in the absence of competition from informed bidders:

$$pf_h(\sigma)(h - r) + (1 - p)f_l(\sigma)(l - r) < 0. \tag{16}$$

This condition is stronger than needed, however. See the proof of Lemma 3 for the appropriate condition.

If (σ, r) given by (12) and (15) are such that uninformed bidders would strictly benefit from deviating and bidding at or above r, then there exists no high-winner-curse equilibrium in which firms use the signal cutoff σ. There exists a "low-winner-curse" equilibrium in which firms still use the signal threshold σ but their reserve price is increasing in the public signal s. Qualitatively, though, the analysis is unaffected (see online appendix E.2).[31] Lemma 3 summarizes these results.

Lemma 3. *A high-winner-curse equilibrium features contracts (σ, r) such that either informed buyers bid h, in which case $\sigma = +\infty$, and $r = h$, or (σ, r) solves*

$$F_l(\sigma) - F_h(\sigma)q_0 = \beta, \tag{17}$$

$$\frac{f_h(\sigma)q_0}{f_l(\sigma)} = \frac{1 + \frac{1}{p(h-r)}}{1 + \frac{\lambda q_1}{q_0(1-q_0)}}. \tag{18}$$

Conversely, if l is sufficiently small (satisfies (16)), all equilibria are high-winner-curse. Any solution (σ, r) to $\{(17); (18)\}$ corresponds to an equilibrium, and so does possibly the second-best case such that $\sigma = +\infty$, and $r = h$.

If l is not sufficiently small for this to hold, there exists a perfect Bayesian equilibrium that shares all characteristics of the high-winner-curse equilibrium, except that the reserve price is a continuously increasing function of $s \leq \sigma$: $r(s) = \max\{r; \rho(s)\}$ where $\rho(.)$ is strictly increasing. A sufficient condition for this equilibrium to satisfy the Intuitive Criterion is $(1 - q_0)^2 \geq q_0 q_2$.

Proof. See the appendix. ■

[31] Here we only sketch low-winner-curse equilibria because we will not study them in the remainder of the paper. The online appendix details their characterization.

The rest of the paper focuses on high-winner-curse equilibria for conciseness. To do so, we suppose from now on that l is sufficiently small that the existence and number of equilibria can be described as follows as β varies other things being equal:

Proposition 4. ***(Equilibria with endogenous resale prices)***

- *There exists a unique equilibrium in which the signal cutoff σ satisfies $f_h(\sigma)q_0 \geq f_l(\sigma)$. It is a high-winner-curse equilibrium $(\overline{\sigma}, \overline{r})$. If $\beta > 1 - q_0$, $(\overline{\sigma}, \overline{r})$ is the unique solution to $\{(17); (18)\}$ such that $f_h(\sigma)q_0 \geq f_l(\sigma)$. If $\beta \leq 1 - q_0$, it corresponds to the second-best in which $\overline{\sigma} = +\infty$ and the good asset is sold at price h with probability $\beta/(1 - q_0)$.*
- *There may also exist an equilibrium such that $f_h(\sigma)q_0 \leq f_l(\sigma)$ which induces higher agency costs than the equilibrium $(\overline{\sigma}, \overline{r})$.*

Proof. The results in Proposition 4 are easy to see from Figure 2, which depicts the left-hand side of the incentive-compatibility constraint (17). We show that equilibria are as described in the proposition provided l is sufficiently small.

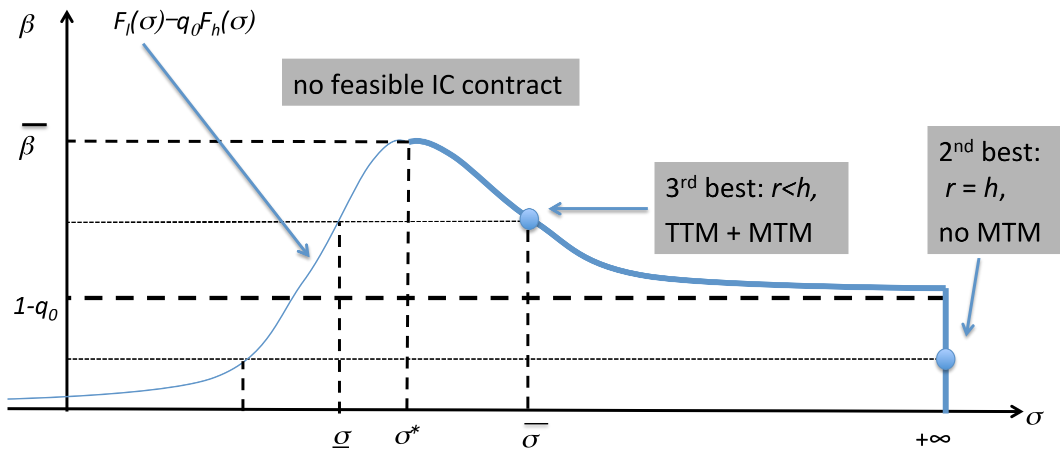

Figure 2. Equilibria for three values of β.

Inspection of Figure 2 shows that for every $\beta \in (1 - q_0, \overline{\beta}]$, the incentive-compatibility constraint (17) has a unique solution $\overline{\sigma}$ where the function $F_l - q_0 F_h$ is decreasing ($f_h(\overline{\sigma})q_0 \geq f_l(\overline{\sigma})$). The right-hand side of the first-order condition (18) increases strictly from $1/[1 + \lambda q_1/[q_0(1 - q_0)]] < 1$ to $+\infty$ as r spans $(-\infty, h)$, and so there is a unique $\overline{r}$ associated with $\overline{\sigma}$. Furthermore, the signal cutoff $\overline{\sigma}$ is bounded below by the maximand of $F_l - q_0 F_h$, σ^*, which does not depend on l when β spans $(1 - q_0, \overline{\beta}]$. The same reasoning as in the proof of Lemma 3 then implies that for l sufficiently small, for every $\beta \in (1 - q_0, \overline{\beta}]$ there exists a high-winner-curse equilibrium associated with $\overline{\sigma}$, and that this is the unique equilibrium satisfying $f_h(\overline{\sigma})q_0 \geq f_l(\overline{\sigma})$.

Inspection of Figure 2 also shows that for every $\beta \in (0, \overline{\beta}]$, the incentive-compatibility constraint (17) has a unique solution $\underline{\sigma}$, increasing in β, where the function $F_l - q_0 F_h$ is increasing ($f_h(\underline{\sigma})q_0 \leq f_l(\underline{\sigma})$). Since (18) defines r as an increasing function of σ, there exists $\underline{\beta}$ such that for each $\beta \in [\underline{\beta}, \overline{\beta}]$, there exists a (unique) $\underline{r}$ such that $(\underline{\sigma}, \underline{r})$ satisfies (18). For the l selected above, there exists $\beta_l \in [\underline{\beta}, \overline{\beta}]$ (possibly equal to $\overline{\beta}$) such that for $\beta \in [\beta_l, \overline{\beta}]$, $(\underline{\sigma}, \underline{r})$ corresponds to a high-winner-curse equilibrium, and this is the unique equilibrium satisfying $f_h(\sigma)q_0 \leq f_l(\sigma)$. For lower values of β, $\underline{\sigma}$ may be associated with an equilibrium with a contingent reserve price whose construction is detailed in online appendix E.2, and $\underline{\sigma}$ is no longer associated with such an equilibrium as β becomes even lower.

The proof of Lemma 3 establishes that the second-best is an equilibrium if and only if $\beta \leq 1 - q_0$.

Finally, we show that for a given β, the equilibrium associated with $\overline{\sigma}$ comes with lower agency costs than that associated with $\underline{\sigma}$ (if any). This is obvious when $\overline{\sigma} = +\infty$. Otherwise, using the incentive-compatibility constraint (17) and the expression of informed buyers' profits (13), the agency costs for high-winner-curse equilibria can be re-written

$$1 - \beta + p\beta + F_h(\sigma) \left[\frac{\lambda p q_1 (h - r)}{1 - q_0} - q_0 \right]. \tag{19}$$

Using condition (18), the term in square brackets is strictly positive (negative) if $f_h q_0 / f_l < 1$ ($f_h q_0 / f_l > 1$), and so the agency costs are larger than $1 - \beta + p\beta$ if $f_h q_0 / f_l < 1$ and smaller if $f_h q_0 / f_l > 1$. That an equilibrium with cutoff $\underline{\sigma}$ and a contingent reserve price also induces higher agency costs than $(\overline{\sigma}, \overline{r})$ follows from a similar argument. Intuitively, the contingent reserve price is still sufficiently lower than the reserve price $\overline{r}$ that the result still holds. ■

The intuition for equilibrium multiplicity can be found in the assumption that buyers do not observe firms' contracts, but rather base their bids on their (correct) expectations for them. Firms in turn write their contracts based on their (correct) expectations for the distributions of bids. In equilibrium, contracts must be optimal given the distribution of bids and bids must be optimal given contracts. Buyers who expect a contract with a very low reserve price place low bids. Expecting this, firms find it optimal to allow for resales at low prices, as incurring the resale discount is still cheaper than incentivizing on the basis of the public signal and thereby rewarding luck. This vindicates buyers' beliefs. Conversely, firms that expect aggressive bids impose higher reserve prices that justify aggressive bids. Contract optimality requires that the signal cut-off σ be consistent with the reserve price, and thus be low (high) when the reserve price is low (high). That the equilibrium incentive-compatibility constraint (17) pinning down σ has two solutions allows for the possibility of two equilibria for some parameter values.

In the illiquid equilibrium such that $f_h q_0/f_l < 1$, firms rely on mediocre market data to reward their agents, asset sales are rare and occur at distressed prices upon the realization of very negative signals. This illiquid equilibrium is inefficient in the sense that it comes at a higher agency cost for firms than the liquid one. Yet, the illiquid equilibrium is unstable whereas the liquid one is stable and constrained-efficient in the following sense. Suppose that an abstract regulation prevents firms from rewarding their agents based solely on the signal for signal realizations $s < \sigma'$. We deem such regulated contracts "σ'-contracts".

Proposition 5. ***(Regulating marking to market)***

- *The illiquid equilibrium corresponding to $\underline{\sigma}$ is unstable: For every $\sigma' \in (\underline{\sigma}, \overline{\sigma}]$, the only equilibrium with σ'-contracts is the one with the contract $(\overline{\sigma}, \overline{r})$.*
- *The liquid equilibrium $(\overline{\sigma}, \overline{r})$ is constrained efficient: If $\sigma' > \overline{\sigma}$, there is no equilibrium with incentive-compatible σ'-contracts.*

Proof. See the appendix. ■

In other words, it is possible to move the economy towards the equilibrium with the lowest agency costs with a simple lower bound σ' on the value of the signal that firms can use to reward agents. The broad intuition why the inefficient equilibrium is unstable is as follows. Because $f_h q_0/f_l < 1$ at this equilibrium, imposing an increase in the cut-off σ raises the agent's incentives to behave. Firms would like to respond with higher reserve prices because they can then afford a lower probability of successful resale. But since buyers always at least match this reserve price, this probability cannot decrease in equilibrium, and the reserve price and signal cut-off must keep increasing until the efficient equilibrium is reached. On the other hand, when this efficient equilibrium features a finite $\overline{\sigma}$, such a regulation of marking to market, if too tight ($\sigma' > \overline{\sigma}$), destroys firms' ability to write incentive-compatible contracts at all.

Implementation: Imposing a higher degree of accounting conservatism

The abstract regulation of the cutoff σ described in Proposition 5 admits a concrete interpretation under the implementation with the accounting measure introduced in Section I.C. It corresponds to a regulation of the degree of conservatism α used when measuring firm value. Since $H(r) = q_0$ in equilibrium, an equilibrium contract (σ, r) is implemented with an accounting measure that uses an equilibrium degree of conservatism

$$\alpha(\sigma) = \frac{pf_h(\sigma)[1 - q_0]}{pf_h(\sigma) + (1 - p)f_l(\sigma)} \tag{20}$$

that depends only on the equilibrium signal cut-off σ.[32]

One can ensure that the economy reaches the efficient equilibrium simply by imposing a degree of conservatism within $(\alpha(\underline{\sigma}), \alpha(\overline{\sigma})]$. In other words, forcing firms to recognize latent gains in a less aggressive fashion than they find privately optimal in the inefficient equilibrium ensures that the economy reaches the efficient equilibrium.

B. Extensions

This section offers two extensions of the baseline model solved in Section A. We first develop a version of the model in which firms can compete with each other for liquidity by posting contracts. This extension will show that the multiplicity of equilibria unveiled in Section A disappears with price posting and, later, will enable us to decompose the contractual externalities that firms create for each other into their impact on the resale cost and that on the informativeness of market data. We then consider the situation in which firms must write contracts before observing the liquidity λ in the market. This yields interesting insights into the suspension of fair-value accounting decided during the 2008 financial crisis. We suppose in this section that the matching of buyers and firms is urn-ball.[33]

B.1. Equilibrium with posted contracts

This section studies a version of the model in which firms post contracts to which they can commit. Buyers can direct their match after observing these contracts. Firms and buyers interact as follows. We assume that each firm $i \in [0,1]$ posts a contract $C(i) = (\sigma(i), r(i))$. Observing these contracts, buyers decide on a p.d.f. f with support in $[0,1]$ that describes the probability $f(i)$ of matching with each firm $i \in [0,1]$. We focus on symmetric equilibria in which all buyers select the same f. Their matching processes are independent, so that firm i faces a number of buyers that is Poisson distributed with parameter $\lambda f(i)$. Buyers do not observe how many other bidders are matched with the same firm as them. An equilibrium is then characterized by $\{C(i); f(i)\}_{i\in[0,1]}$ such that:

1. Each buyer expects the same profit conditionally on being matched to each firm i such that $f(i) > 0$, weakly higher than that associated with firms such that $f(i) = 0$.

2. For every $i \in [0,1]$, there does not exist a contract C' and a Poisson intensity λ' such that, other things being equal, i) firm i would incur strictly lower agency costs if it was posting C' rather than $C(i)$ and facing a distribution of buyers with Poisson parameter λ' rather than

[32] Expression (20) simply stems from injecting $H(r) = q_0$ in (9).

[33] We also still suppose l sufficiently small that uninformed buyers find bidding below l optimal in the equilibria that we consider.

$\lambda f(i)$; ii) buyers expect the same profit conditional on a match with i given $\{C'; \lambda'\}$ than under $\{C(i); \lambda f(i)\}$.

This equilibrium concept borrows from the competitive search equilibrium developed by Guerrieri, Shimer, and Wright (2010).[34] It formalizes the idea that at the equilibrium, a firm cannot find it optimal to deviate and post an alternative contract.

Recall that the efficient equilibrium when contracts are unobserved is associated with a contract $(\overline{\sigma}, \overline{r})$ when $\beta \in (1 - q_0, \overline{\beta}]$, and corresponds to the second-best for $\beta \leq 1 - q_0$. When firms post contracts, we have:

Proposition 6. ***(Equilibrium with posted contracts)*** *There exists a unique equilibrium in which all firms post the same contract, and buyers match uniformly across them ($f = \mathbb{1}_{[0,1]}$):*

- *If $\beta > 1 - q_0$, firms post the contract $(\overline{\sigma}, r^P)$, where $r^P < \overline{r}$. They incur higher agency costs than in the efficient equilibrium with unobserved prices because buyers bid less aggressively.*
- *If $\beta \leq 1 - q_0$, the equilibrium contract consists in selling the good asset at price h with probability $\beta/(1 - q_0)$(second-best).*

Proof. See the appendix. ■

Proposition 6 first confirms that the assumption that buyers cannot observe contracts is the key source of equilibrium multiplicity in our baseline model. The commitment of firms to publicly announced contracts eliminates the possibility of equilibria with the inefficient low signal cut-off $\underline{\sigma}$. On the other hand, each firm internalizes the impact of its contract on liquidity in the secondary market for its asset. As a result, firms seek to steal liquidity from each other. When the number of informed buyers is small (so that $q_0 > 1 - \beta$), this competition for liquidity leads to lower reserve prices than in the efficient equilibrium with unobserved contracts. In sum, this equilibrium with posted contracts eliminates the inefficient equilibrium in the baseline model but raises agency costs in the efficient one, unless there are sufficiently many buyers that the second-best is attained (an outcome that cannot prevail in a long-term configuration as we will see in Section III).

B.2. Uncertain liquidity and suspension of fair-value accounting

We suppose here that contracts are unobserved as in Section A, but that firms must write contracts before observing the mass of informed buyers λ. Firms share the prior that λ is distributed according to the c.d.f. Λ with bounded support within $(0, +\infty)$. After agents have exerted their

[34]Our setup is considerably simpler than theirs, in which one side of the market is heterogeneous and privately informed. On the other hand, buyers here have a choice (bid) beyond which seller to go to.

forecasting effort, the value of λ is publicly observed by firms and buyers, and buyers submit bids.[35] The optimal equilibrium contract is in this case contingent on the realization of λ. It is easy to see that for each realization of λ, the optimal contract has the same structure with signal cut-off and reserve price $(\sigma(\lambda), r(\lambda))$ as in the baseline model. For brevity we focus on equilibria that are stable and high-winner-curse for every realization of λ.[36] We have:

Proposition 7. ***(Uncertain liquidity)*** *The equilibrium contract is such that the reserve price is a constant r and the signal threshold $\sigma(\lambda)$ is an increasing function of λ.*

Proof. See the appendix. ∎

In the presence of uncertain liquidity, firms equate the marginal cost of a resale across realizations of liquidity λ by setting a constant reserve price r. Because the average resale cost decreases in λ, firms raise the cut-off above which they reward agents based on the signal as the market becomes more liquid, and thus agents need to resell assets more frequently in order to be rewarded in this case.

During the 2008 financial crisis, regulators across the globe have temporarily suspended marking to market (or marking to model) for several banks' asset classes. The motivation was that without such a suspension, impairments would have resulted in the breach of prudential requirements for many institutions, thereby inducing them to shed these assets in very illiquid markets. The ex-ante optimal rule established in Proposition 7 closely relates to such decisions. Setting a low σ in illiquid times is akin to reducing the negative impact of low market signals on the measure of firms' net wealth, thus making it more likely that they meet a given solvency requirement. This is ex-ante efficient because this reduces the occurence of resales in very illiquid markets.

III. Long-term equilibrium

Finally, we allow the mass λ of informed buyers to be endogenously determined through a free-entry condition. We also endogenize the market signal received by each firm as the imperfect observation of transactions by other firms. Endogenous liquidity λ affects firms' environment by impacting the matching process between firms and informed buyers, and in turn the ease of asset resale and the quality of market data resulting from their interactions. More precisely, we modify the baseline model of Section II as follows.

Free-entry condition. By incurring a cost $\kappa > 0$, an uninformed buyer can acquire knowledge so as to be able to privately observe the payoff of the project once matched to a firm. The mass

[35] Buyers' prior for λ is immaterial given that they bid knowing its realization.

[36] Such equilibria exist if they exist in the model with deterministic λ for every λ in the support of Λ, which we assume.

of informed bidders is therefore now an equilibrium outcome λ. We suppose that the matching of buyers to firms is urn-ball. We rule out coordination failures. There always exists an equilibrium in which there are no informed buyers and the assets are accordingly never resold. This equilibrium, however, is not robust (say, to the exogenous presence of some informed buyers).

Informed trading and signal quality. We suppose that the c.d.f. of the date-1 signal conditional on a payoff $y \in \{h; l\}$ is of the form $F_y(s, \lambda)$, continuously differentiable with respect to λ, and satisfies:

Assumption 1. ***(Informed trading generates better market data.)*** *For all* (s, λ)*,*

$$\frac{\partial F_h(s,\lambda)}{\partial \lambda} \leq 0, \tag{21}$$

$$f_l(s,\lambda)\frac{\partial F_h(s,\lambda)}{\partial \lambda} \leq f_h(s,\lambda)\frac{\partial F_l(s,\lambda)}{\partial \lambda}. \tag{22}$$

In words, F_h must increase with λ in the sense of first-order stochastic dominance, and sufficiently more so than F_l.[37] The online appendix E.6 offers two examples of microfoundations for conditions (21) and (22). In both examples, the signal s of each firm results from its imperfect observation of the prices fetched by the assets sold by other firms. In one microfoundation, the observation is imperfect because of *misclassification risk*: Each firm may assign the wrong types to the projects sold by the other firms. In this case the signal distribution does not depend on λ, and so (21) and (22) hold as equalities. In the other microfoundation, there is no misclassification but observation is imperfect because projects have *idiosyncratic components* and trade for other reasons than the provision of incentives.

Recall from Section II that for a given λ, there may be two high-winner-curse equilibria corresponding to the two solutions in σ of the incentive-compatibility constraint. In this section we restrict the analysis to the constrained-efficient one associated to the largest value of σ for two reasons. First, the inefficient equilibrium is unstable. Second, we are interested in studying whether constrained-efficiency still holds when λ is endogenously determined. Note that the second-best equilibrium whereby $\overline{\sigma} = +\infty$ and $r = h$ can no longer be sustained as the absence of expected profits precludes information acquisition by buyers. As a result, a stable high-winner-curse equilibrium with information acquisition ($\lambda > 0$) must satisfy the first-order condition (18), the incentive-compatibility constraint (17), and a free-entry condition:

[37]Condition (22) obviously holds if F_h increases whereas F_l decreases in λ in the sense of first-order stochastic dominance.

$$\frac{f_h(\sigma,\lambda)q_0(\lambda)}{f_l(\sigma,\lambda)} = \frac{1+\frac{1}{p(h-r)}}{1+\frac{\lambda q_1(\lambda)}{q_0(\lambda)(1-q_0(\lambda))}} > 1, \tag{23}$$

$$F_l(\sigma,\lambda) - F_h(\sigma,\lambda)q_0(\lambda) = \beta, \tag{24}$$

$$pF_h(\sigma,\lambda)\frac{q_1(\lambda)(h-r)}{1-q_0(\lambda)} = \kappa. \tag{25}$$

The equality in condition (23) is the first-order condition, (24) is the incentive-compatibility constraint, and (25) is the free-entry condition stating that the expected bidding profit of an informed buyer is equal to the information acquisition cost κ. The inequality in condition (23) imposes that the equilibrium signal cut-off be $\overline{\sigma}(\lambda)$, the largest solution to (24) in σ given λ. Finally it must also be that uninformed buyers bid l.

Proposition 8. ***(Existence of a stable high-winner-curse equilibrium)*** *There exists $\overline{\kappa}$ such that for all $\kappa \leq \overline{\kappa}$, there exists a stable high-winner-curse equilibrium. The equilibrium agency costs are:*

$$p\beta + 1 - F_l(\overline{\sigma}(\lambda),\lambda) + \lambda\kappa, \tag{26}$$

and so admit the equilibrium value of λ as a sufficient statistic.

Proof. See the appendix. ■

Section II showed that stable high-winner-curse equilibria are constrained-efficient when λ is inelastic. We now show that conversely, they are inefficient when λ responds elastically to firms' accounting choices. To do so, we show that, starting from a stable equilibrium, two different types of public interventions, liquidity support and accounting regulation, both locally reduce firms' agency costs.

Liquidity support. The first type of intervention consists in subsidizing information acquisition with an amount x, so that the cost of information acquisition is $\kappa - x$. This subsidy, financed with a lump-sum tax on principals, may be interpreted as imposing public disclosure requirements on firms.[38]

Accounting regulation. The alternative intervention that we consider rests purely on contracting restrictions. It consists in imposing that firms use a higher degree of accounting conservatism than they find optimal in the unregulated equilibrium. To an unregulated equilibrium (σ, r, λ) corresponds the degree of conservatism:

$$\alpha = \frac{pf_h(\sigma)[1-q_0(\lambda)]}{pf_h(\sigma) + (1-p)f_l(\sigma)}, \tag{27}$$

[38] We could also consider a Pigovian subsidy y to each successful bid. This would however induce firms to sell their l-projects without rewarding their agents in order to pocket the subsidy.

and we impose a small increase in α.[39]

We have:

Proposition 9. ***(Equilibrium efficiency)*** *For every stable equilibrium* (σ, r, λ)*, two types of small public interventions lead to a regulated equilibrium* $(\sigma', r', \lambda') > (\sigma, r, \lambda)$*:*

- *Liquidity support measures that subsidize buyers' information acquisition;*
- *Accounting regulations that impose a higher degree of accounting conservatism.*

The unregulated equilibrium is locally inefficient: Both interventions reduce firms' agency costs.

Proof. See the appendix. ■

Liquidity, as measured by the mass of informed buyers λ, is inefficiently low in the unregulated equilibrium because firms fail to internalize the positive externalities that information acquisition induced by their contracts creates for other firms. There are two types of such positive liquidity externalities. First, a larger pool of informed buyers bid more aggressively and this reduces the expected cost of a resale. Second, more informed buyers also lead to a higher quality of market data through the assumed effect of λ on F_h and F_l. This effect exists only if inequality (22) holds strictly at the equilibrium. Note that firms could do better at internalizing this latter data-quality effect if they held several projects each.[40] Private-equity funds or venture capitalists holding several firms with related activities would internalize that the resale of one of their investments positively affects their ability to credibly value the remaining ones.

Starting from an unregulated stable equilibrium (σ, r, λ), both types of interventions lead to a regulated one whereby $(\sigma', r', \lambda') > (\sigma, r, \lambda)$. This leads in turn to a distribution of informed bids that increases in the sense of first-order stochastic dominance, to more informative signals, and as a result to lower agency costs for firms. In one of the microfoundations for (22) that we offer in the online appendix, the signal s received by each firm is the noisy observation of a sample of bids for projects of the same type as its own one. Thus, the increase in the distribution of bids for h-projects in the sense of first-order stochastic dominance both reduces resale costs, and generates better market data as λ increases. The resale and signal externalities are two sides of the same coin.

Both regulations reduce firms' agency costs and are desirable because they come at no cost due to distortions or/and imperfect enforcement. An interesting route for future research consists in introducing such costs and studying how these interventions should optimally be combined. In

[39]As discussed in more detail below, to be sure, regulating accounting standards does not amount to imposing the accounting measures that firms use for private contracting. In regulated industries such as banking and insurance, however, the measures used by prudential regulation directly affect firms' behavior.

[40]We are grateful to an anonymous referee for making this point.

particular, we believe that accounting standards that make a more or less intensive use of market data affect only partially the degree to which firms do so when contracting with their various stakeholders. Market-based measures become more pervasive in private contracts and regulations once adopted by accounting standards since accounting measures are easier to use than bespoke variables for contracting between heterogeneously informed agents in practice (e.g., in bond covenants or prudential regulation). This is in turn because they are familiar, available at no cost, certified, and easier to verify by courts.[41] Still, to be sure, firms are always free to use whichever information they see fit when contracting, regardless of the prevailing accounting standard. A detailed modelling of the partial influence of accounting standards on regulations and private contracts is an interesting avenue for future research.

Long-term equilibrium with posted contracts

When λ is fixed, the (unique) equilibrium with posted contracts is strictly less efficient than the stable equilibrium with unobserved contracts (unless they both deliver the second-best). Interestingly this is no longer so when λ is determined through a free-entry condition:

Proposition 10. ***(Endogenous liquidity and posted contracts)*** *There exists $\overline{\overline{\kappa}}$ such that for all $\kappa \leq \overline{\overline{\kappa}}$, there exists an equilibrium with posted contracts. These equilibria are locally inefficient if and only if inequality (22) is strict.*

Proof. See the appendix. ■

When firms post contracts they use low reserve prices in order to steal liquidity from each other. When aggregate liquidity is fixed, they merely raise their agency costs by transferring more rents to the fixed pool of informed buyers by doing so. When this pool is endogenously determined, the internalization of the effect of their contracts on liquidity by firms is socially beneficial. Recall that with secret contracts, firms fail to internalize two positive liquidity externalities: more competitive resale markets and higher quality of market data. With posted contracts, firms internalize the former externality but still fail to do so with the latter. Hence, the equilibrium is locally inefficient and benefits from public interventions only when (22) holds strictly. Interestingly, (22) is strict in only one of the microfoundations that we offer (idiosyncratic shocks). In the other one (misclassification), an equilibrium with posted contracts is therefore locally efficient.

[41] For example, firms may be reluctant to develop a complex valuation model for the sole purpose of a bond covenant, whereas they would use such a model if it was an accounting measure certified by legally liable auditors and used for prudential regulation.

IV. Extensions

Finally, this section briefly mentions a number of extensions that receive a more detailed treatment in the online appendix.

The agent values date-2 consumption. Suppose that the agent has utility

$$u_0 + u_1 + \delta u_2, \tag{28}$$

where $\delta, u_1, u_2 \in [0,1]$, and that the principal can still provide the agent with utility u_t at cost u_t for $t \in \{1;2\}$. The baseline model corresponds to the case in which $\delta = 0$. The second-best case without measurement frictions corresponds to $\delta = 1$. When $\delta \in (0,1)$, the optimal contract is still of the form (σ, r) at date 1, where both σ and r increase in δ, and features a unit payment with some probability at date 2 in case of a high payoff realization. Recent international accounting standards require that firms whose business model consists in holding assets to maturity, as opposed to trading them more frequently, should, broadly, rely less on market-based measures. In accordance with these regulatory practices, the comparative statics predict that if the agent has a higher δ, then firms resell their assets less often (higher r), and also rely less on market data (higher σ).

Alternative welfare criteria. We have assumed that the principal owns the project and that the social criterion coincides with the principal's welfare. Both assumptions can be questioned. First, the social welfare function may put positive weight on the agent's welfare. Second, the agent may own the project but need to finance the investment from a competitive capital market; then the question is not to aggregate welfares (the investors are competitive and therefore enjoy no surplus), but that the maximization of the agent's welfare involves a shadow price associated with the financing constraint. The online appendix[42] shows that in either case the objective function—that of the social planner in the first case, and that of the agent in the second—can be subsumed to a convex combination of managerial compensation and the cost of resale at discounted prices:

$$\min_{\{\sigma,r\}} \left\{ \omega(p\beta + 1 - F_l(\sigma)) + (1-\omega)pF_h(\sigma) \int_r^h (h-t)dH(t) \right\}, \tag{29}$$

where $\omega \in [0, 1/2]$. For a given liquidity level λ, a higher relative weight on the resale cost—as happens when the social planner puts more weight on the agent—leads to a lower resale frequency and therefore to a more intense use of fair value accounting. The key insights of the paper remain valid. The laissez-faire equilibrium generates too little liquidity. The two externalities (informativeness of the market signals and resale discount) are still present.

Informed buyers make false negative/positive errors. We also study a simple form of imperfect information whereby the buyers matched to a firm may with some probability receive the same

[42]The online appendix further extends the analysis to allow for costly utility transfers, allowing for further comparative statics.

misleading signal about the asset. The case of false-negative mistakes (a h payoff is mistaken for a l payoff) is identical to an increase in the probability q_0 that no buyer is matched with the firm. In the case of false-positive mistakes (a l payoff is mistaken for a h payoff), the analysis is somewhat more cumbersome. One can show, however, that the optimal contract is of the form $(\sigma, r(s))$, such that the reserve price is monotonic in the firm's public signal s. Firms are willing to sell at a higher discount when their public signal is higher because they are less likely to sell an l-payoff asset given such signals.

V. Discussion and concluding remarks

This paper augments a standard agency-based model of corporate finance with a measurement friction. It offers a theory of privately and socially optimal accounting in an environment in which both contractual relations between firms' stakeholders and liquidity in the market for firms' assets are the endogenous outcome of optimizing behaviors.

Gains trading arises naturally in privately optimal contracts as a substitute for relying on market data (marking to market). These contracts admit a natural implementation with an accounting measure that recognizes latent capital gains with an appropriate degree of conservatism.

Laissez-faire generically leads to a socially insufficient degree of accounting conservatism. When the liquidity of firms' assets is exogenously given, inefficient equilibria may arise whereby firms rely too much on market data of poor quality and sell their assets at excessively deep discounts following negative market signals. With endogenous asset liquidity, the equilibrium exhibits a form of "bootstrapping." It is inefficient because firms fail to internalize the externalities that they create for each other when contracting on transactions by other firms rather than on their own transactions. In the equilibrium with unobserved contracts, firms fail to internalize two positive liquidity externalities: more competitive resale markets and more informative market data. A higher degree of conservatism would enable firms to trade their assets at a lower cost, and would enhance the quality of market data. With posted contracts, firms internalize the former externality but still fail to do so with the latter.

Our model admits broader interpretations. The transaction cost of learning the value of one's asset was traced to buyer market power in the resale market. Relatedly, the rents of informed buyers could stem from the presence of noise trading[43]; the firm can then control the extent of market monitoring by affecting the liquidity of the market for its asset (through ownership concentration or the easiness with which shares can be traded), rather than by setting a reserve price like in our model. Again there would be externalities, since more active trading would benefit other firms

[43] As in for instance Holmström-Tirole (1993) on the monitoring role of the stock market.

through the presence of a larger community of informed traders and more informative transaction prices. In another reinterpretation of the model, the informed buyers would be capital constrained at date 1 when purchasing resold assets (as in the classic fire sales literature) and would accordingly accumulate costly reserves at date 0. The prospect of advantageous acquisitions would make them hoard more reserves, making asset markets more liquid at date 1. Again there would be an externality and too much reliance on marking to market from the industry's point of view.

An interesting feature of the model for the political economy of accounting is that the total agency costs for firms are split into expected payments to firms' agents and informed buyers. Assuming as we have done that informed buyers and sellers are different entities[44], the less conservative the recognition of latent gains, the larger the fraction of these payments that accrue to insiders: Rewards for luck are more likely when the signal cut-off is lower. Managers benefit from a higher degree of marking to market. More generally, the study of the political economy of accounting choices would be worth expanding upon.

There are many other interesting routes for future research. For instance, firms' balance sheets are in practice comprised of very heterogeneous items. Consider for example the case of an insurance company with marketable assets backing complex and illiquid liabilities. We could formalize this in an extension in which firms run several "projects" for which market signals and resale options vary. Another important question in the design of accounting norms is that of the optimal degree of standardization across heterogeneous industries or/and countries. We believe that our framework is a useful starting point for an economic analysis of the trade-offs at stake.

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[44]This need not be the case; a firm might be on the selling side in some states of nature and on the buying side in others, depending on the liquidity shocks it itself faces; see e.g. chapters 7 and 8 in Holmström-Tirole (2011), which however do not consider the measurement issues that are central to this paper.

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Appendix

Proof of Proposition 1

Step 1. Design of the optimal contract

Bids below or equal to l are uninformative and thus there cannot be a benefit from selling below l (and there will be a loss if the sale is at a discount). Let b denote the set of genuine bids strictly above l received by the firm (equal to $\emptyset$ if the firm receives no such bid). The same offer can be made by several bidders, in which case each is counted as an element of the set. Let $\hat{b}$ denote the set of bids strictly above l announced by the agent. That the agent can issue fake bids implies $b \subseteq \hat{b}$. Let $x_k(s, \hat{b})$ denote the probability that the principal asks for a resale at the k^{th} bid $\hat{b}_k$ of $\hat{b}$, and

(30) $$x(s, \hat{b}) = \sum_k x_k(s, \hat{b}) \in [0, 1],$$

with $x(s, \emptyset) = 0$.

The revelation principle implies that we can focus on direct incentive-compatible mechanisms that elicit truth-telling: $\hat{b} = b$. If a resale fails to go through because the bid is fake, it is clearly optimal to let the agent receive zero utility. More generally, let us denote by $u(s, b)$ the utility that a given direct mechanism grants to the agent when the signal realization is s and the set of legitimate bids strictly above l received by the firm is b. For $y \in \{l; h\}$ and every signal realization s, we also let

(31) $$U_y(s) = E_b[u(s, b) \mid s, y].$$

Truth-telling implies that

(32) $$U_l(s) = u(s, \emptyset).$$

Finally, we denote $c_h(s)$ the expected cost of resales associated with this mechanism given s and $y = h$:

(33) $$c_h(s) = E_b\left[\sum_k x_k(s, b)(h - b_k) \mid s, h\right].$$

Let $u_0(s, b)$ denote the payoff to the agent if there is no resale (the agent receives this payoff with probability $1 - x(s, b)$). Truth-telling implies:

(34) $$u(s, \emptyset) \geq (1 - x(s, b))u_0(s, b) \text{ for all } b,$$

otherwise the agent would issue some fake bids b if the signal is s and the firm receives no bid above l. Furthermore, for all b,

$$u(s,b) \leq x(s,b) + (1 - x(s,b))u_0(s,b) \leq x(s,b) + u(s,\emptyset), \tag{35}$$

which together with $u(s,b) \leq 1$ implies

$$u(s,b) \leq \min\{1, x(s,b) + u(s,\emptyset)\} = u(s,\emptyset) + \min\{1 - u(s,\emptyset), x(s,b)\}, \tag{36}$$

and in turn

$$U_h(s) \leq u(s,\emptyset) + E_b[\min\{1 - u(s,\emptyset), x(s,b)\} \mid s, h]. \tag{37}$$

The optimal contract must then solve:

$$\min_{\{U_h(.),u(.,\emptyset),x(.,.)\}} \left\{ \int [pf_h(s)\,[U_h(s) + c_h(s)] + (1-p)f_l(s)u(s,\emptyset)]\, ds \right\} \tag{38}$$

subject to the ex-ante incentive constraint

$$\int [f_h(s)U_h(s) - f_l(s)u(s,\emptyset)]\, ds \geq \beta, \tag{39}$$

and, for all s, the ex-post truthtelling constraint

$$U_h(s) \leq u(s,\emptyset) + E_b[\min\{1 - u(s,\emptyset), x(s,b)\} \mid s, h]. \tag{40}$$

Condition (39) is the ex-ante incentive-compatibility constraint ensuring that the agent exerts effort, and condition (40) is the incentive constraint for truth telling about bids (plus feasibility $x(s,b) \leq 1$).[45] Note that the incentive constraints depend only on $x(s,b)$ and not on its allocation among the $x_k(s,b)$. So the minimization of c_h requires choosing the highest bid in b (or no bid at all). And so for $b \neq \emptyset$, $c_h(s) = E_b[x(s,b)(h - \max_{\{b_k \in b\}} b_k)|s,h]$. The optimal policy therefore depends only on the distribution $H(t)$ of the highest bid for asset h (there is no point picking $x(s,b) \neq x(s,b')$ for $b \neq b'$ but $\max_{\{b_k \in b\}} b_k = \max_{\{b_k \in b'\}} b_k$, since both have the same informational content concerning the agent's performance).

Furthermore, a simple inspection of the program shows that at the optimal contract, (39) and (40) must be binding. Substituting (40) into (39), and $\int [pf_h(s)U_h(s) - pf_l(s)u(s,\emptyset)]\, ds$ with $p\beta$

[45] As is standard, we ignore other ex-post constraints when solving this program. It will be evident that the solution satisfies them.

in (38) yields a Lagrangian:

$$\mathcal{L} = -\int \left[f_l(s)u(s,\emptyset) + pc_h(s)f_h(s)\right] ds - p\beta \tag{41}$$

$$+\,\mu \left[\int \left[(f_h(s) - f_l(s))u(s,\emptyset) + f_h(s)E_b[\min\{1-u(s,\emptyset), x(s,b)\} \mid s,h]\right] ds - \beta\right]$$

$$= \int \begin{bmatrix} \left[\mu - (\mu+1)\frac{f_l(s)}{f_h(s)}\right] u(s,\emptyset) \\ +\mu E_b[\min\{1-u(s,\emptyset), x(s,b)\} \mid s,h] - pc_h(s) \end{bmatrix} f_h(s)ds$$

$$-\,\mu\beta - p\beta, \tag{42}$$

where μ is the shadow price of (39). Letting $\hat{x}(s,t) \equiv x(s,b)$ for $t = \max_{b_k \in b}\{b_k\}$, the Lagrangian can be rewritten

$$\mathcal{L} = \int \begin{bmatrix} \left[\mu - (\mu+1)\frac{f_l(s)}{f_h(s)}\right] u(s,\emptyset) \\ +\int \left[\mu \min\{1-u(s,\emptyset), \hat{x}(s,t)\} - p(h-t)\hat{x}(s,t)\right] dH(t) \end{bmatrix} f_h(s)ds$$

$$-\,\mu\beta - p\beta. \tag{43}$$

It is optimal to set $\hat{x}(s,t) = 1 - u(s,\emptyset)$ for all t such that $p(h-t) \leq \mu$ and $\hat{x}(s,t) = 0$ otherwise. Accordingly, we define

$$r = \inf\{t \in [r_-, h] \mid p(h-t) \leq \mu\}, \tag{44}$$

and

$$\hat{x}(s,t) = \mathbb{1}_{\{t \geq r\}}(1 - u(s,\emptyset)). \tag{45}$$

This yields

$$\mathcal{L} = \int \begin{bmatrix} \left[\mu H(r) + p\int_r^h (h-t)dH(t) - (\mu+1)\frac{f_l(s)}{f_h(s)}\right] u(s,\emptyset) \\ +\int_r^h \left[\mu - p(h-t)\right] dH(t) \end{bmatrix} f_h(s)ds$$

$$-\,\mu\beta - p\beta, \tag{46}$$

and the monotonicity of f_l/f_h implies that there exists σ such that $u(s,\emptyset) = \mathbb{1}_{\{s \geq \sigma\}}$.

Overall, the optimal contract rewards the agent if the signal is above σ or if it is not and a resale is executed above r.

Step 2. Characterization of r and σ

As a result, the optimal contract corresponds to a pair (σ, r) that solves

$$\min_{\{\sigma,r\}} \left\{ p\beta + 1 - F_l(\sigma) + pF_h(\sigma)\int_r^h (h-t)dH(t) \right\} \tag{47}$$

s.t.

$$F_l(\sigma) - H(r)F_h(\sigma) = \beta, \tag{48}$$

$$r_- \leq r \leq r_+. \tag{49}$$

If there exists no σ such that

$$F_l(\sigma) - q_0 F_h(\sigma) = \beta, \tag{50}$$

then there exists no contract that elicits high effort.

Looking for an interior solution (that is, ignoring (49)), the first-order condition reads:

$$\frac{f_h(\sigma)}{f_l(\sigma)} = \frac{p(h-r)+1}{p\int_r^h H(t)dt} \equiv T(r). \tag{51}$$

The system of equations {(48);(51)} has at most one solution (σ, r). It is best seen graphically on Figure 3.

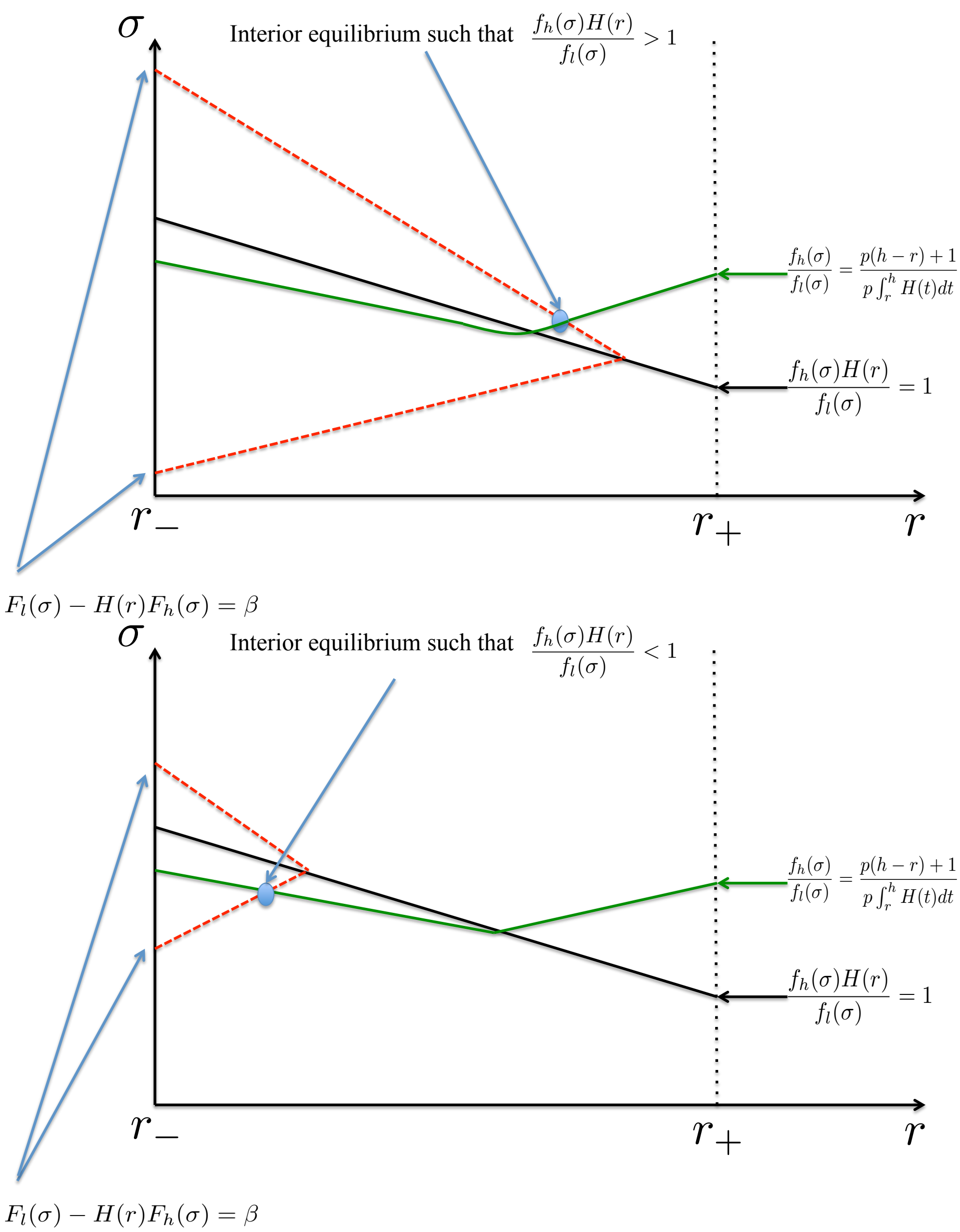

Figure 3. First-order condition and incentive-compatibility constraint in the (r,σ) plane. Each graph shows a possible configuration for the IC constraints. The upper one corresponds to a low β, the lower one to a high β.

The equation $[f_h(\sigma)/f_l(\sigma)]H(r) = 1$ defines a decreasing frontier in the plane (r, σ) over $r \in [r_-, r_+]$. The first-order condition (51) implicitly defines σ as first decreasing in r below this frontier and then increasing above it over $[r_-, r_+]$. The incentive-compatibility condition defines implicitly two thresholds σ as functions of $r \in [r_-, r_+]$, one that is increasing and lies below the frontier and one that is decreasing and lies above it. These two graphs intersect at the frontier at the maximum value of r for which there exists at least one σ such that the incentive-compatibility constraint is satisfied.

From Figure 3, it is easy to see that there is at most one (σ, r) that solves $\{$(48);(51)$\}$. If there is no solution, then the contract is a corner solution that can be of three types:

1. The contract is (σ, r_+), where σ is the largest solution to $F_l(\sigma) - F_h(\sigma) = \beta$, such that $f_h(\sigma)/f_l(\sigma) > T(r_+)$.
2. The contract is (σ, r_-), where σ is the largest solution to $F_l(\sigma) - q_0 F_h(\sigma) = \beta$, such that $f_h(\sigma)/f_l(\sigma) < T(r_-)$.
3. The contract is (σ, r_-), where σ is the smallest solution to $F_l(\sigma) - q_0 F_h(\sigma) = \beta$, such that $f_h(\sigma)/f_l(\sigma) > T(r_-)$.

Intuitively, type 1 corresponds to the situation in which the bids are so low that the firm relies exclusively on the signal and never resells its project. Type 2 corresponds to the case in which bids are sufficiently close to h that the firm finds it optimal to rely as much as possible on resales, but $1 - q_0 < \beta$ forces it to rely on the signal as well. Type 3 is the situation in which resales are very expensive but the firm is very constrained and needs to use them a lot. In this case it seeks to set the signal cutoff at the lowest possible incentive-compatible value so as to minimize the ex-ante frequency of resales.

Graphically, these three cases correspond to three configurations in which the graph corresponding to the first-order condition does not intersect with any of the two dotted curves associated with the incentive-compatibility constraint in Figure 3, either because it is in between them (type 1), above them (type 2), or below them (type 3).

Proof of Lemma 3

Consider a high-winner-curse equilibrium.

Step 1: Contracts and informed bidding strategies

Step 1 in the proof of Proposition 1, establishing that the optimal contract must be of the form (σ, r), applies to any distribution of the highest bid H provided informed bids are above l and do not depend on s. Any contract in a high-winner-curse equilibrium must therefore be of this form. We show that this implies that bidding strategies are either degenerate or must have a differentiable c.d.f. (For brevity we omit the proof that bidding strategies are symmetric conditionally on the bidder's type.) If a bidding strategy has h in its support then it must be a Dirac delta at h since bidders must be indifferent between all bids. Suppose a bidding strategy does not include h in its support. (We tackle equilibria with all bids equal to h at the end of this proof.) If it had an atom at some point of its support (necessarily strictly smaller than h), bids in a right neighborhood of this point would strictly dominate a bid at this point, which cannot be the case. So H is continuous.

We then show that the lower bound of the support of S, r_-, is equal to the reservation price r anticipated by bidders. It must be that $r_- \geq r$ because bids below r are not accepted whereas bids above are accepted with a strictly positive probability and thus yield a strictly positive profit. Suppose $r_- > r$. We know from the above that S is atomless at r_-. This implies that bidding r strictly dominates bidding r_-, which cannot be the case. Thus $r = r_-$.

We then compute π, the expected profit of an informed buyer. We have just seen that the distribution of bids S is atomless with support of the form $[r, r_+] \subset [r, h]$. Thus the ex-ante (before matching) expected profit π of a bidder satisfies:

$$\text{For all } t \in [r, r_+],\ pF_h(\sigma) \sum_{k \geq 1} \frac{q_k}{1-q_0}(h-t)S^{k-1}(t) = \pi \tag{52}$$

which for $t = r$ yields

$$\pi = \frac{pF_h(\sigma)q_1(h-r)}{1-q_0}. \tag{53}$$

Furthermore, expression (52) implies that S and therefore H are differentiable, and so the first-order condition characterizing the optimal contract in Step 2 in the proof of Proposition 1 applies.

Step 2: Equilibrium incentive-compatibility constraint and first-order condition in an interior equilibrium

There are λ buyers per firm on average so the expected resale cost for a firm is

$$pF_h(\sigma) \int_r^h (h-t)dH(t) = \lambda\pi. \tag{54}$$

The incentive-compatibility constraint (17) is derived in the body of the paper, and the first-order condition (18) stems from

$$\frac{f_h(\sigma)}{f_l(\sigma)} = \frac{p(h-r)+1}{pH(r)(h-r) + p\int_r^h (h-t)dH(t)}, \tag{55}$$

$$H(r) = q_0, \tag{56}$$

$$p\int_r^h (h-t)dH(t) = \frac{\lambda p q_1(h-r)}{1-q_0}. \tag{57}$$

Step 3: Elimination of corner equilibria

Suppose a high-winner-curse equilibrium features corner contracts ((15) is slack). We know that $r = r_-$ and so type-1 corner equilibria in which $r = r_+$ are ruled out. We focus on corner equilibria of types 2 and 3. We generalize the standard forward induction argument to the case of multiple informed agents by considering a deviation by one bidder, fixing other bidders' equilibrium strategies. So the "sender" is a given bidder and the "receiver" the firm. Conditional on a given public signal s (the dependence on which we will omit for notational simplicity), the sender's action is a bid t. The receiver's action is a state-and-bid-contingent acceptance of a bid—that of the sender or of other bidders—or of no bid at all. The sender's utility is an expected payoff given his expectations over bids by other bidders and the firm's decision. The sender can be of three types—informed of an h-payoff, informed of an l-payoff, or uninformed. The latter two types make zero profit in equilibrium, while all types make zero profit when deviating to $t \in (l, r)$ as this offer is rejected.

To apply the Intuitive Criterion, we need to define the receiver's best response to arbitrary bids and arbitrary beliefs about the sender's type. If the largest bid received by the firm is larger than r, then rejecting $t \in (l, r)$ is the unique element of any best response. If all other bids are below or at l (the other possibility given presumed equilibrium behavior for the other bidders), then any probability of executing t can be optimal for some beliefs about the bidder's type provided (15) is slack and t is sufficiently close to r.

If t is sufficiently close to (but below) r, an uninformed bidder cannot obtain a profit that exceeds the equilibrium level (equal to 0) from a receiver's best response, as this would contradict the assumption of a high-winner-curse equilibrium (and a fortiori nor can an informed bidder knowing l). By contrast, a sender informed about an h-payoff increases his profit relative to the equilibrium profit provided the receiver puts all the weight on the sender's knowing that $y = h$.

From the Intuitive Criterion, the bid t should then be interpreted as coming from a bidder who is informed of an h-payoff, and therefore the receiver should choose to accept it when there is no higher offer. Thus the Intuitive Criterion rules out equilibria in which condition (15) is slack.

Step 4: Equilibria are high-winner-curse ones when l is sufficiently small

Steps 1, 2 and 3 show that any high-winner-curse equilibrium with bids strictly below h must be such that (σ, r) satisfies (17) and (18). We now show that for l sufficiently small, all the equilibria with nondegenerate bids are exactly the high-winner-curse equilibria defined by the (zero, one, or two) (σ, r) that solve $\{(17); (18)\}$.

Note first that the reasoning leading to condition (43) in the proof of Proposition 1 holds even when H depends on s. Condition (43) shows that $\sigma = \inf\{s \mid u(s, \emptyset) = 1\}$ is finite. It also shows that firms never accept bids below $r = h - \frac{\mu}{p}$, where μ and thus r do not depend on l because (43) is the Lagrangian of a program that does not. Thus, a sufficient condition for uninformed bidders to make a strict loss when bidding at or above r is that l satisfies:

$$pf_h(\sigma)h + (1-p)f_l(\sigma)l < [pf_h(\sigma) + (1-p)f_l(\sigma)]r. \tag{58}$$

For such an l, informed bids such that $r_-(s) = r(s) > r$ can be eliminated using the Intuitive Criterion as in Step 3 and thus in equilibrium it must be that $r_-(s) = r$. The indifference argument in (52) that leads to the determination of S then implies that if the reserve price is non-contingent on s, then so is S and therefore H.

This establishes that under (58) an equilibrium must be a high-winner-curse one. Finally, noting that there are at most two solutions (σ, r) to $\{(17); (18)\}$, one can choose l sufficiently small that they both correspond to a high-winner-curse equilibrium.

Of course, condition (58), which presumes that the uninformed bidder wins whenever $y = h$ (i.e. that he faces no competition from the informed) is simple but stronger than needed. More generally, a necessary and sufficient condition for the uninformed not to want to bid above l when bidders use symmetric bidding strategies $S(.)$ is that for all $t \geq r$

$$pf_h(s)[q_0(h-t) + q_1 S(t)(h-r)] \leq (1-p)f_l(s)(t-l). \tag{59}$$

See online appendix E.2 for a proof of the more general version of (59) when informed bids are state-contingent. Surprisingly, the binding constraint may not be the possibility that the uninformed bid r, but rather that they bid a t greater than r. Online appendix E.2 shows, though, that a sufficient condition for (59) to reflect only the fact that the uninformed may bid r:

$$pf_h(s)q_0(h-r) \leq (1-p)f_l(s)(r-l). \tag{60}$$

is $q_0 q_2 \geq (1-q_0)^2$. Online appendix E.2 also demonstrates the existence of, and characterizes equilibria with state-contingent reservation prices when (59) is violated.

Equilibria with degenerate bids

If $\beta \leq 1 - q_0$, then the second-best in which $\sigma = +\infty$ and the good asset is sold at price h with probability $\beta/(1-q_0)$ is clearly an equilibrium. This second-best is not an equilibrium if $\beta > 1 - q_0$ because an infinite σ cannot be incentive-compatible, and an equilibrium with a finite σ and $r = h$ would not survive our refinement.

Proof of Proposition 5

It is easy to see that an optimal σ'-contract consists in rewarding the agent based on a signal larger than $\sigma^R \geq \sigma'$ and allowing him to sell the asset above some reserve price otherwise, where σ^R may be infinite. That the incentive-compatibility constraint must be binding, and that the equilibrium probability of resale is q_0 whenever resale is allowed, imply that for every $\sigma' \in (\underline{\sigma}, \overline{\sigma}]$, the only equilibrium with σ'-contracts is the one with the contract $(\overline{\sigma}, \overline{r})$. If $\sigma' > \overline{\sigma}$, there is no equilibrium with incentive-compatible σ'-contracts.

Proof of Proposition 6

In equilibrium, each firm $i \in [0,1]$ takes as given the profit k that buyers expect from matching with other firms, and offers a contract (σ', r') rationally anticipating that this will attract a Poisson intensity λ' such that

$$pF_h(\sigma')\frac{q_1(\lambda')(h-r')}{1-q_0(\lambda')} = k, \tag{61}$$

where $q_k(\lambda)$ is defined in (10). Firm i also expects all bids to be above the reserve price, so that the equilibrium probability of a failure to resale is $q_0(\lambda')$. It proves convenient to write firm i's program with the control variables (σ, λ) rather than (σ, r):

$$\min_{\{\sigma',\lambda'\}} \{1 - F_l(\sigma') + \lambda' k\} \tag{62}$$

s.t.

$$F_l(\sigma') - q_0(\lambda')F_h(\sigma') = \beta. \tag{63}$$

An equilibrium is then characterized by (σ, r) such that the solution to this program is attained at (σ, λ) when $k = pF_h(\sigma)q_1(\lambda)(h-r)/(1-q_0(\lambda))$.

The first-order condition to the firm's program reads:[46]

$$\frac{f_h(\sigma')q_0(\lambda')}{f_l(\sigma')} = 1 - \frac{q_0'(\lambda')F_h(\sigma')}{k} > 1. \tag{64}$$

Suppose first that the incentive-compatibility constraint (17) admits two solutions, and recall that we denote the largest by $\overline{\sigma}$. Then the solution (σ', λ') to the firm's contracting problem, given by $\{(63); (64)\}$, must be equal to $(\overline{\sigma}, \lambda)$ in equilibrium. Injecting the equilibrium value of k in

[46] We also checked that the second-order condition for a minimum is globally satisfied.

(64), this implies that firms post an equilibrium reserve price r_P implicitly defined as

$$\frac{f_h(\overline{\sigma})q_0(\lambda)}{f_l(\overline{\sigma})} = 1 + \frac{1}{\frac{pq_1(\lambda)(h-r^P)}{q_0(\lambda)(1-q_0(\lambda))}} \tag{65}$$

Comparing (65) and (18) at the same value of σ shows that $r^P < \overline{r}$ for a given $\overline{\sigma}$.

Finally, suppose that the incentive-compatibility constraint (17) admits only one solution. Then the first-order condition is slack and the unique equilibrium yields the second-best outcome.

Proof of Proposition 7

The proof that the optimal contract contract must be of the form $(r(\lambda), \sigma(\lambda))$ when λ is revealed only at date 1 is very similar to that of Step 1 in the proof of Proposition 1 and we skip it. The optimal contract $(r(\lambda), \sigma(\lambda))$ solves

$$\max_{(r(.),\sigma(.))} \left\{ \int \left[1 - F_l(\sigma(\lambda)) + pF_h(\sigma(\lambda)) \int_{r(\lambda)}^{h} (h-t) \frac{\partial H(t,\lambda)}{\partial t} dt \right] d\Lambda(\lambda) \right\} \tag{66}$$

$s.t.$

$$\int \left[F_l(\sigma(\lambda)) - H(r(\lambda),\lambda) F_h(\sigma(\lambda)) \right] d\Lambda(\lambda) = \beta \tag{67}$$

The first-order condition yields

$$r(\lambda) = r, \tag{68}$$

$$\frac{f_h(\sigma(\lambda))}{f_l(\sigma(\lambda))} = \frac{p(h-r)+1}{p\int_r^h H(t,\lambda)dt}. \tag{69}$$

It only remains to show that $H(t, \lambda)$ increases strictly in λ in the sense of first-order stochastic dominance ($\partial H/\partial\lambda < 0$) . Note first that the distribution of bids $S(., \lambda)$ satisfies

$$\sum_{k\geq 1} \frac{q_k(\lambda)}{q_1(\lambda)} (h-t) S^{k-1}(t,\lambda) = h - r. \tag{70}$$

That q_k/q_1 strictly increases in λ implies that $S(t, \lambda)$ must strictly decrease w.r.t. λ for all t. Second,

$$H = \sum_{k\geq 0} q_k S^k \tag{71}$$

implies that so does H.

Proof of Proposition 8

Uninformed bidders have a perfectly elastic demand at any price below l. For ϵ sufficiently small, for each λ such that $(1 - q_0(\lambda)) \in [\beta - \epsilon, \beta)$, there exists a unique σ such that (24) holds and $f_h q_0 / f_l > 1$ for (λ, σ). Continuity implies that the set of σ defined this way is an interval $[\sigma_1, +\infty)$. Further, differentiating the incentive-compatibility (24) constraint yields:

$$\frac{\partial \sigma}{\partial \lambda} = \frac{\frac{\partial q_0}{\partial \lambda} F_h + q_0 \frac{\partial F_h}{\partial \lambda} - \frac{\partial F_l}{\partial \lambda}}{f_l - q_0 f_h} > 0 \tag{72}$$

because

$$q_0 \frac{\partial F_h}{\partial \lambda} - \frac{\partial F_l}{\partial \lambda} \leq \frac{\partial F_h}{\partial \lambda} \left(q_0 - \frac{f_l}{f_h} \right) \leq 0. \tag{73}$$

from conditions (21) and (22).

For any $\sigma \geq \sigma_1$, one can then uniquely define $\lambda(\sigma)$ and $r(\sigma)$ such that (24) and (25) are satisfied for $(\sigma, r(\sigma), \lambda(\sigma))$. Define then $\Sigma(\sigma)$ as the solution to (23) for such $(r(\sigma), \lambda(\sigma))$. For κ sufficiently small, $r(\sigma)$ takes values in a compact set that is sufficiently close to h and thus $\Sigma(\sigma) \geq \sigma_1$ for all $\sigma \geq \sigma_1$. Also, Σ is bounded from above because $\lambda(\sigma)$ and $r(\sigma)$ take values in compact sets. Denoting σ_2 this upper bound, Σ is an (obviously continuous) mapping over $[\sigma_1, \sigma_2]$ and thus admits a fixed point. This fixed point σ and the associated value of λ given by (24) and r from (25) form a stable equilibrium by construction.

Proof of Proposition 9

We first prove that the public interventions mentioned in the proposition have the claimed impact, and then we show that this impact reduces firms' agency costs.

Liquidity support measures. If information acquisition is subsidized by an amount x, then the equilibrium is characterized by the conditions $\{(23); (24); (25)\}$ up to replacing κ with $\kappa - x$.

Consider an unregulated ($x = 0$) high-winner-curse stable equilibrium (σ, r, λ). For x sufficiently small, one can apply the same reasoning as that in the proof of Proposition 8 and arrive at a mapping Σ_x that has a fixed point σ' arbitrarily close to σ. This fixed point σ' and the associated value of λ' given by (24) and r' from (25) form a (stable) regulated equilibrium. Let us show that $(\sigma', r', \lambda') > (\sigma, r, \lambda)$. We first show that $\Sigma_x > \Sigma$. This stems from the fact that for given σ, λ, (25) generates a value of r that increases in x, and then the right-hand side of (23) is increasing in r. That $\Sigma_x > \Sigma$ implies $\sigma' > \sigma$, and from (72) this implies in turn that $\lambda' > \lambda$. To see that $r' > r$, one can rewrite (25) as:

$$p[F_l(\sigma, \lambda) - \beta] \frac{q_1(\lambda)(h - r)}{q_0(\lambda)(1 - q_0(\lambda))} = \kappa - x. \tag{74}$$

This shows that an increase in σ and λ while satisfying (24) also yields an increase in r in (25) since $q_1/q_0(1-q_0)$ increases in λ, and (22) imply:

$$f_l + \frac{\partial F_l}{\partial \lambda}\frac{\partial \lambda}{\partial \sigma} \geq \frac{\partial \lambda}{\partial \sigma}\frac{\frac{\partial q_0}{\partial \lambda}F_h}{\left(1-\frac{q_0 f_h}{f_l}\right)} > 0. \tag{75}$$

In addition, r clearly increases w.r.t. x in (25) holding σ and λ constant.

Regulating accounting conservatism. To a high-winner-curse stable equilibrium corresponds the degree of accounting conservatism defined in (9):

$$\alpha = \frac{pf_h(\sigma)[1-q_0(\lambda)]}{pf_h(\sigma)+(1-p)f_l(\sigma)}. \tag{76}$$

Since (24) implicitly defines σ as increasing in λ from (72) whereas (76) defines σ as decreasing in λ, imposing a degree of conservatism α' strictly larger than but sufficiently close to α leads to a regulated equilibrium in which firms are forced to use a signal cut-off $\sigma' > \sigma$ and this must lead to a liquidity level $\lambda' > \lambda$. The proof that this in turn yield $r' > r$ from (25) is identical to the one above using expression (74).

Stable equilibria are inefficient. Consider a high-winner-curse stable equilibrium (σ, r, λ). Given λ, the equilibrium contract (σ, r) must coincide with the solution in (σ', r') of firms' contracting problem:

$$\min_{(\sigma', r')} V(\sigma', r'; \lambda, r) = 1 - F_l(\sigma', \lambda) + pF_h(\sigma', \lambda)\int_{r'}^{h}(h-t)\frac{\partial H(t,\lambda,r)}{\partial t}dt \tag{77}$$

s.t.

$$F_l(\sigma', \lambda) - F_h(\sigma', \lambda)H(r', \lambda, r) = \beta. \tag{78}$$

The Lagrangian of this program is

$$\mathfrak{L} = -V(\sigma', r'; \lambda, r) + \mu[F_l(\sigma', \lambda) - F_h(\sigma', \lambda)H(r', \lambda, r) - \beta]. \tag{79}$$

The first-order condition w.r.t. r' yields $\mu = p(h - r')$. The envelope theorem then yields that at the equilibrium values $(\sigma', r') = (\sigma, r)$

$$\begin{aligned}
\frac{\partial \mathfrak{L}}{\partial \lambda} &= -\left[[1+p(h-r)]\frac{\partial F_l(\sigma,\lambda)}{\partial \lambda} - \frac{\partial F_h(\sigma,\lambda)}{\partial \lambda}\left[p\int_r^h H(t,\lambda,r)dt\right]\right] \\
&\quad + pF_h(\sigma,\lambda)\int_r^h \frac{\partial H(t,\lambda,r)}{\partial \lambda}dt, \\
\frac{\partial \mathfrak{L}}{\partial r} &= pF_h(\sigma,\lambda)\int_r^h \frac{\partial H(t,\lambda,r)}{\partial r}dt.
\end{aligned}$$

The first-order condition (6) and condition (22) imply that

$$[1+p(h-r)]\frac{\partial F_l(\sigma,\lambda)}{\partial\lambda}-\frac{\partial F_h(\sigma,\lambda)}{\partial\lambda}\left[p\int_r^h H(t,\lambda,r)dt\right]$$

is positive in equilibrium.

Also, the equilibrium distribution of an informed bid, $S(.,\lambda,r)$, is given by:

$$\sum_{k\geq 1}\frac{q_k(\lambda)}{q_1(\lambda)}(h-t)S^{k-1}(t,\lambda,r)=h-r, \tag{80}$$

That q_k/q_1 increases w.r.t. λ for all $k\geq 1$ implies that $S(t,\lambda,r)$ must decrease w.r.t. λ for all r, t. It is also transparent from (80) that $S(t,\lambda,r)$ decreases in r for all λ, t. Also,

$$H=\sum_{k\geq 0}q_k S^k \tag{81}$$

implies that H increases in the sense of first-order stochastic dominance when S and $\{q_k\}$ do. Overall this implies $\partial V/\partial\lambda<0$, $\partial V/\partial r<0$.

As a result, any regulation leading to small increases in σ, r, and λ reduces firms' agency costs because an increase in σ has no first-order impact on firms' agency costs from the envelope theorem whereas increases in λ and r reduce them from the above.

Proof of Proposition 10

An equilibrium with posted contract and free entry is a triplet (σ,r,λ) such that (σ,λ) is the solution to

$$\min_{\{\sigma',\lambda'\}}\{1-F_l(\sigma',\lambda)+\lambda'\kappa\} \tag{82}$$

s.t.

$$F_l(\sigma',\lambda)-q_0(\lambda')F_h(\sigma',\lambda)\geq\beta, \tag{83}$$

and the triplet satisfies

$$pF_h(\sigma,\lambda)\frac{q_1(\lambda)(h-r)}{1-q_0(\lambda)}=\kappa. \tag{84}$$

The equilibrium is thus characterized by:

$$\frac{f_h(\sigma,\lambda)q_0(\lambda)}{f_l(\sigma,\lambda)}=1+\frac{1}{\frac{pq_1(\lambda)(h-r)}{q_0(\lambda)(1-q_0(\lambda))}}, \tag{85}$$

$$F_l(\sigma,\lambda)-q_0(\lambda)F_h(\sigma,\lambda)=\beta, \tag{86}$$

$$pF_h(\sigma,\lambda)\frac{q_1(\lambda)(h-r)}{1-q_0(\lambda)}=\kappa, \tag{87}$$

where (85) is the first-order condition from firms' program. A solution to this system can be constructed as a fixed point the very same way as in the proof of Proposition 8.

The Lagrangian of $\{(82); (83)\}$ is

$$\mathfrak{L} = F_l(\sigma', \lambda) - \lambda' \kappa + \mu(F_l(\sigma', \lambda) - q_0(\lambda')F_h(\sigma', \lambda) - \beta). \tag{88}$$

The envelope theorem then yields that at the equilibrium values $(\sigma', \lambda') = (\sigma, \lambda)$

$$\frac{\partial \mathfrak{L}}{\partial \lambda} = (1 + \mu) \left(\frac{\partial F_l(\sigma, \lambda)}{\partial \lambda} - \frac{\partial F_h(\sigma, \lambda)}{\partial \lambda} \frac{f_l(\sigma, \lambda)}{f_h(\sigma, \lambda)} \right),$$

which yields the result.

Online appendix: Extensions

This appendix states and proves various results that extend the results discussed throughout the paper.

E.1. Second-order condition for program $\{(3);(4)\}$

The Lagrangian of the program can be written

(E.1) $$L(\sigma, r, \nu) = -f(\sigma, r) + \nu g(\sigma, r)$$

where

(E.2) $$f(\sigma, r) = p\beta + 1 - F_l(\sigma) + pF_h(\sigma)\int_r^h (h-t)dH(t),$$

(E.3) $$g(\sigma, r) = F_l(\sigma) - H(r)F_h(\sigma).$$

We need to compute the determinant of the bordered Hessian matrix

(E.4) $$\begin{bmatrix} 0 & -g_\sigma & -g_r \\ -g_\sigma & L_{\sigma\sigma} & L_{\sigma r} \\ -g_r & L_{r\sigma} & L_{rr} \end{bmatrix}.$$

We have

(E.5) $$L_\sigma = f_l - pf_h\int_r^h (h-t)dH(t) + \nu(f_l - H(r)f_h) = 0,$$

(E.6) $$L_r = p(h-r)F_h\frac{dH(r)}{dr} - \nu F_h\frac{dH(r)}{dr} = 0 \to \nu = p(h-r),$$

(E.7) $$L_{\sigma r} = p(h-r)f_h\frac{dH(r)}{dr} - \nu f_h\frac{dH(r)}{dr} = 0,$$

(E.8) $$L_{r\sigma} = p(h-r)f_h\frac{dH(r)}{dr} - \nu f_h\frac{dH(r)}{dr} = 0,$$

(E.9) $$L_{rr} = -pF_h\frac{dH(r)}{dr},$$

(E.10)
$$L_{\sigma\sigma} = f_l' - pf_h'\int_r^h (h-t)dH(t) + \nu(f_l' - H(r)f_h') = f_l(1+p(h-r))(f_l'/f_l - f_h'/f_h),$$

(E.11)
$$g_\sigma = f_l - H(r)f_h,$$

(E.12)
$$g_r = -\frac{dH(r)}{dr}F_h.$$

This yields a determinant

$$(H(r)f_h - f_l)^2 pF_h \frac{dH(r)}{dr} + F_h^2 f_l[1 + p(h-r)] \left(\frac{dH(r)}{dr}\right)^2 (f_h'/f_h - f_l'/f_l) > 0. \tag{E.13}$$

E.2. Low-winner-curse equilibria in Section II

Suppose a solution (σ, r) to $\{(17); (18)\}$ is such that uninformed bidders would find bidding above r profitable. We construct a low-winner-curse equilibrium such that firms' contracts consist in the signal cut-off σ and reserve prices $r(s)$ that weakly increase with respect to the public signal s.

Step 1. We define for every realization of the public signal s the minimum reserve price for which uninformed bidders find bidding l optimal. For every $\rho \in (l, h]$, we first define $S(., \rho)$ as

$$\begin{cases} S(t,\rho) = 0 & \text{if } t \leq \rho, \\ \sum_{k\geq 1} q_k (h-t) S^{k-1}(t,\rho) = q_1(h-\rho) & \text{for all } t \in \left[\rho, h - \frac{q_1(h-\rho)}{1-q_0}\right], \\ S(t,\rho) = 1 & \text{if } t \geq h - \frac{q_1(h-\rho)}{1-q_0}. \end{cases} \tag{E.14}$$

$S(., \rho)$, a decreasing function of ρ, is the c.d.f. of an informed bid if the bidder believes the reserve price is ρ and uninformed bidders bid below l. An uninformed bidder observing a public signal $s \leq \sigma$ does not find it profitable to bid $t \geq \rho$ if and only if

$$pf_h(s)H(t,\rho)(h-t) \leq (1-p)f_l(s)(t-l). \tag{E.15}$$

This inequality holds for all $s \leq \sigma$, $t \geq \rho$ if and only if it holds at $s = \sigma$ for all t from the monotonicity of f_h/f_l. We have

$$H(t,\rho) = \sum_{k\geq 0} q_k S(t,\rho)^k = q_0 + (1-q_0)S(t,\rho) \sum_{k\geq 1} \frac{q_k}{1-q_0} S^{k-1}(t,\rho) \tag{E.16}$$

$$= q_0 + q_1 S(t,\rho) \frac{h-\rho}{h-t}. \tag{E.17}$$

from (E.14). This implies that bidding t is not profitable if and only if:

$$pf_h(\sigma)[q_0(h-t) + q_1 S(t,\rho)(h-\rho)] \leq (1-p)f_l(\sigma)(t-l). \tag{E.18}$$

Define then for all public signal s

(E.19)

$$\rho(s) = \inf\{\rho \mid \textit{For all } t \geq \rho,\ pf_h(s)[q_0(h-t) + q_1 S(t,\rho)(h-\rho)] \leq (1-p)f_l(s)(t-l)\}.$$

This set is not empty because (E.18) is satisfied for ρ sufficiently close to h, and is bounded below because it is not satisfied for ρ sufficiently close to l. Thus $\rho(s)$, the smallest reserve price at which uninformed bidders find bidding l optimal, is well defined for all s. The monotonicity of f_h/f_l implies that $\rho(s)$ is increasing as the infimum of a set that decreases with s.

Step 2. Suppose that a firm expects a distribution of informed bids $H(., s)$ that is contingent on the public signal s, and such that $H(\rho(s), s) = q_0$ for all s. With such contingent informed bids, the firm's program reads:

$$\min_{\{\sigma, r(s)\}} \left\{ \; p\beta + 1 - F_l(\sigma) + \textstyle\int_{-\infty}^{\sigma} p f_h(s) \int_{r(s)}^{h} (h-t) dH(t,s) ds \; \right\} \tag{E.20}$$

s.t.

$$F_l(\sigma) - \int_{-\infty}^{\sigma} H(r(s), s) f_h(s) ds = \beta, \tag{E.21}$$

$$\rho(s) \leq r(s). \tag{E.22}$$

Ignoring the feasibility constraint, the first-order condition with respect to $r(s)$ yields that $h - r(s)$ must be constant. At the optimal contract, the reserve price is therefore either a constant r', or such that the firm accepts all bids strictly above $\rho(s)$ when $\rho(s) > r'$.

Step 3. Expecting such contracts, uninformed bidders find bidding below l optimal by construction of $\rho(s)$ and informed bidders mix their bids above $\inf\{r'; \rho(s)\}$. The monotonicity of $\rho(s)$ therefore implies that their minimum bid is r' below a signal cut-off $\sigma' < \sigma$ and $\rho(s)$ for $s \in [\sigma', \sigma]$. Thus, the value of r' is pinned down by the first-order conditions w.r.t. r' ($\mu = p(h - r')$) and σ:

$$\frac{f_h(\sigma)}{f_l(\sigma)} = \frac{p(h-r')+1}{p(h-r')q_0 + p\int_{\rho(\sigma)}^{h}(h-t)dH(t,\sigma)}, \tag{E.23}$$

$$= \frac{p(h-r')+1}{p(h-r')q_0 + \frac{\lambda p q_1 (h-\rho(\sigma))}{(1-q_0)}}. \tag{E.24}$$

If (E.24) is not satisfied for any $r' > l$, then if σ is such that $f_h(\sigma)q_0/f_l(\sigma) \geq 1$, the equilibrium is such that the reserve price is $\rho(s)$ for all value of s (that is, $\sigma' = -\infty$), and

$$\frac{f_h(\sigma)}{f_l(\sigma)} \leq \frac{p(h-l)+1}{p(h-l)q_0 + \frac{\lambda p q_1 (h-\rho(\sigma))}{(1-q_0)}}. \tag{E.25}$$

If $f_h(\sigma)q_0/f_l(\sigma) < 1$, then there exists no low-winner-curse equilibrium associated with σ.

This low-winner-curse-equilibrium survives the Intuitive Criterion in the case in which uninformed bidders are indifferent between bidding l and $\rho(s)$ for all $s \in [\sigma', \sigma]$. In this case, uninformed bidders would benefit from bidding $\rho(s) - \epsilon$ for ϵ sufficiently small if this offer is accepted with strictly positive probability, and so the Intuitive Criterion does not rule out firms' beliefs that such a bid may stem from an uninformed bidder.

A sufficient condition ensuring that the no-mimicking constraint binds at $\rho(s)$ when it binds is $q_0 q_2 \geq (1-q_0)^2$. This holds indeed if for all $t \in (\rho(s), r_+(s))$,

$$\frac{\partial}{\partial t}[pf_h(s)[q_0(h-t)+q_1 S(t,\rho)(h-\rho(s))]-(1-p)f_l(s)(t-l)] \leq 0, \tag{E.26}$$

which in turn holds if

$$\frac{\partial S}{\partial t} \leq \frac{q_0}{q_1(h-\rho(s))}. \tag{E.27}$$

From (E.14),

$$q_2 S \leq q_1 \frac{t-\rho(s)}{h-t}, \tag{E.28}$$

and

$$(t-\rho(s))\frac{\partial S}{\partial t} \leq \frac{h-\rho(s)}{h-t} S. \tag{E.29}$$

Combining both expressions and noticing that $t \leq r_+(s) = h - q_1(h-\rho(s))/(1-q_0)$ yields the result.

E.3. The agent values date-2 consumption

Throughout the paper, we take the agent's reward date as fixed ($t=1$) for expositional simplicity. In this section, we more generally follow the literature on incentives provision for agents with liquidity needs[1] and assume that delaying compensation to date 2 involves a social cost. Suppose that the agent derives utility at both dates 1 and 2 and has preferences

$$u_0 + u_1 + \delta u_2, \tag{E.30}$$

where $\delta, u_1, u_2 \in [0,1]$. The principal can still provide the agent with utility u_t at cost u_t for $t \in \{1;2\}$. The baseline model corresponds to the case in which $\delta = 0$. The second-best case without measurement frictions corresponds to $\delta = 1$. It is straightforward to extend the analysis of the optimal contract to the case in which $\delta \in (0,1)$.

In case of a date-1 resale, the price reveals the project's payoff, and thus the principal knows it at date 2. If the firm holds on to the asset until date 2, the payoff is revealed at this date. This implies that either way, the principal knows the payoff at date 2. The information conveyed by the date-1 signal and resale (if any) is thus immaterial at this date. Also, the cost of providing

[1] See e.g. Aghion et al (2004), or Faure-Grimaud-Gromb (2004).

utility at date 2 is independent of any utility already provided at date 1. Thus, one can without loss of generality consider only contracts whereby the date-2 compensation does not depend on the contracting history, only on the realized payoff. Denote (σ, r, τ) such a contract. It is such that the agent is rewarded at date 1 if the signal is above σ, or if it is below σ and he manages to sell the project at a price above r. He may also be rewarded at date 2 with probability τ if the project pays off h. Ignoring feasibility constraints, an optimal contract solves the counterpart of {(3),(4)}

$$\min_{\{\sigma,r,\tau\}} \left\{1 - F_l(\sigma) + pF_h(\sigma)\int_r^h (h-t)dH(t) + p(1-\delta)\tau\right\} \tag{E.31}$$

s.t.

$$F_l(\sigma) - H(r)F_h(\sigma) + \delta\tau = \beta. \tag{E.32}$$

For brevity, we discuss only the case in which the optimal contract corresponds to an interior solution of this program. The interior solution is then characterized by (E.32) and two first-order conditions:

$$\frac{f_h(\sigma)}{f_l(\sigma)} = \frac{p(h-r)+1}{p\int_r^h H(t)dt}, \tag{E.33}$$

$$h - r = \frac{1-\delta}{\delta}. \tag{E.34}$$

It is then obvious that an increase in δ, starting from a contract such that $f_h H/f_l > 1$, yields an increase in σ, r, and τ.

This extension of the model bears interesting relationship to the accounting standard IFRS 9 issued in 2014. In this standard, the business model used by an entity for managing an asset affects the measurement of this asset. The "hold and collect" business model, whereby firms acquire assets to collect their cash flows until maturity, is the one that corresponds to a lower use of marking to market. In line with this, this simple extension predicts that firms with more patient agents (a higher δ other things being equal) rely more on the "hold to collect" model and, at the same time, rely less on market data because (σ, r, y) increases in δ. Thus we rationalize this connection between "business model" and measurement regime.

E.4. Alternative welfare criteria

Here we suppose that the agent has preferences over dates 0 and 1 consumptions, c_0 and c_1,

$$c_0 + \delta \min\{c_1, 1\}, \tag{E.35}$$

where $\delta \in (0,1]$. The private benefit from shirking, B, is enjoyed at date 0, and so becomes B/δ from the point of view of the principal. Transferring expected date-1 utility u to the agent costs u/δ to the principal. We consider both the situation in which the principal owns the project and that in which the agent owns it and faces a competitive financial market. We normalize the reservation utility of the principal to 0 and suppose that that of the agent is always below the rewards that the optimal contract grants him (for example, because it is also equal to 0). The agent is cashless at date 0.

A. The principal is the owner of the project

Let c denote the expected resale costs, w the expected date-1 reward of the agent, and i the investment cost. Let $T \geq 0$ denote a date-0 lump-sum transfer from the principal to the agent.[2] The owner receives $ph + (1-p)l - i - w - c - T$ and the agent $\delta w + T$. And so, for social welfare weights α_P and α_A, the social welfare function is (up to a constant)

$$W = \alpha_P(-w - c - T) + \alpha_A(\delta w + T) = -\alpha_P c - (\alpha_P - \delta\alpha_A)w + (\alpha_A - \alpha_P)T, \tag{E.36}$$

and the principal's individual rationality constaint is

$$ph + (1-p)l - i - c - w \geq T. \tag{E.37}$$

If (E.37) is slack at the optimum then it must be that $\alpha_P \geq \alpha_A$, otherwise welfare could be increased by increasing T. If $\alpha_P < \alpha_A$ then (E.37) is binding and the objective is (up to a multiplicative constant α_A)

$$-[(1-\delta)w + c]. \tag{E.38}$$

In the case in which the social planner cannot implement lump-sum transfers, the social welfare function is simply

$$-\alpha_P c - (\alpha_P - \delta\alpha_A)w. \tag{E.39}$$

This implies overall:

Proposition E.1. ***(Alternative welfare criteria)*** *If the planner can implement lump-sum transfers, or if he cannot but uses weights such that $\alpha_P \geq \delta\alpha_A$, then the optimal contract minimizes a convex combination of expected resale costs and expected rewards to the agent that puts weakly more weight on expected resale costs. The case of equal weights is the one studied in the paper.*

[2] Ignoring date-1 lump-sum transfers is without loss of generality since date-0 transfers weakly dominate them from $\delta \leq 1$.

B. The agent is the owner of the project

Under a competitive capital market, the agent solves $\max\{\delta w+T\}$ subject to the investors' break-even constraint: $ph+(1-p)l-i-w-c-T\geq 0$. This constraint clearly optimally binds and so the agent seeks to minimize again $(1-\delta)w+c$.

In sum, under all these alternative social objectives, the objective in the optimal contracting problem can always be expressed with weights $\omega\in[0,1/2]$ on pure date-1 utility transfers and $1-\omega$ on resale costs:

$$\min_{\{\sigma,r\}}\left\{\omega(p\beta'+1-F_l(\sigma))+(1-\omega)pF_h(\sigma)\int_r^h(h-t)dH(t)\right\} \tag{E.40}$$

s.t.

$$F_l(\sigma)-H(r)F_h(\sigma)=\beta', \tag{E.41}$$

$$r_-\leq r\leq r_+, \tag{E.42}$$

where $\beta'=\beta/\delta$.

This program is identical to {(3),(4)}, up to putting different weights on rewards for luck and on resale costs in the objective and to scaling β. The first-order condition (which may be slack if the feasibility contraint (E.42) binds) is simply:

$$\frac{f_h(\sigma)}{f_l(\sigma)}=\frac{p(h-r)+1-\frac{1-2\omega}{1-\omega}}{p\int_r^h H(t)dt}. \tag{E.43}$$

It is easy to see from (E.41) and (E.43) that the analysis conducted in the paper when $\omega=1/2$ carries over:

Optimal contracting problem in Section 2. One can see from Figure 3 how this different objective affects the analysis. Replacing condition (6) with (E.43) amounts to shifting downwards the curve associated with (6) in the plane (r,σ), all the more so because ω is small. This downwards shift implies a higher reliance on market data (a lower σ). As in the case studied in the paper, the optimal contract may either be below or above the frontier $[f_h(\sigma)/f_l(\sigma)]H(r)=1$ depending on the parameters.

Equilibria with exogenous λ in Section 3. The equilibra cut-off σ do not depend on ω as they correspond to solutions to (E.41). Furthermore, (E.43) implies that the reserve price r associated with a given σ decreases with respect to ω. In other words, as the objective puts a smaller penalty on rewards for luck, bidders understand that firms are more reluctant to rely on resales, thereby setting more aggressive reserve prices. Accordingly, they bid more aggressively.

Endogenous λ in Section 4. Here again, it is easy to see that the analysis of stable high-winner-curse equilibria carries over. Firms fail to internalize the same liquidity externalities as in the case $\omega=1/2$.

E.5. Informed buyers make false negative/positive errors

Suppose that in Section II, all informed buyers matched to a firm with an h-payoff project receive the same incorrect signal that the payoff is l with probability ϵ_h (false negatives). Similarly, all buyers matched to a firm with an l-payoff project receive the same incorrect signal that the payoff is h with probability ϵ_l (false positives). We suppose $\epsilon_h + \epsilon_l < 1$. For brevity, we suppose that parameters are such that uninformed bidders optimally bid l in the relevant range.

Whereas this is immaterial when buyers are perfectly informed, we explicitly assume here that informed buyers observe the public signal received by the firm. As a result, an informed buyer who receives a low-payoff private signal and observes a public signal s expects a project's payoff

$$l(s) = \frac{p\epsilon_h f_h(s)h + (1-p)(1-\epsilon_l)f_l(s)l}{p\epsilon_h f_h(s) + (1-p)(1-\epsilon_l)f_l(s)}, \tag{E.44}$$

whereas a buyer who receives a high-payoff private signal and observes a public signal s updates to:

$$h(s) = \frac{p(1-\epsilon_h)f_h(s)h + (1-p)\epsilon_l f_l(s)l}{p(1-\epsilon_h)f_h(s) + (1-p)\epsilon_l f_l(s)} > l(s). \tag{E.45}$$

Bidding game. All informed bidders for a given project share the same information about the payoff so that as in the perfect-information case, there is no uncertainty about other bidders' valuations.

Optimal contracts. We suppose that for each signal realization s, bids have the same properties as in the baseline model replacing h and l by $h(s)$ and $l(s)$, and we denote by $H(.,s)$ the distribution of the highest bid for a high-payoff project. (As in the baseline model, these properties are satisfied in equilibrium.) The same reasoning as in Step 1 in the proof of Proposition 1 shows that firms' optimal contract is of the form $(\sigma, r(s))$. The agent is rewarded for a signal above σ, or for a resale above $r(s)$ when $s \le \sigma$. One can show that the optimal contract solves (ignoring feasibility constraints)

$$\min_{\{\sigma, r(s)\}} \left\{ \begin{array}{l} p\beta + 1 - F_l(\sigma) + \epsilon_l \int_{-\infty}^{\sigma} f_l(s)(1 - H(r(s),s))ds \\ + \int_{-\infty}^{\sigma} \left[[p(1-\epsilon_h)f_h(s) + (1-p)\epsilon_l f_l(s)] \int_{r(s)}^{h(s)} (h(s) - t)dH(t,s) \right] ds \end{array} \right\} \tag{E.46}$$

s.t.

$$(1-\epsilon_l)F_l(\sigma) - \epsilon_h F_h(\sigma) - \int_{-\infty}^{\sigma} H(r(s),s)[(1-\epsilon_h)f_h(s) - \epsilon_l f_l(s)]ds = \beta, \tag{E.47}$$

Comparing with the baseline model with perfect information ($\epsilon_h = \epsilon_l = 0$) the additional terms admit straightforward interpretations. Regarding the objective (E.46), false positives introduce additional rewards for luck due to the fact that an l-asset may be successfully resold (term $\epsilon_l \int f_l(1-$

H)). Unlike rewards for luck induced by high signals on l-projects, these also come at resale costs. On the other hand, expected resale costs of h-projects are reduced by false negatives for a given signal and reserve price.

The incentive-compatibility constraint is best interpreted in equilibrium when all bids are above the reserve price $r(s)$ for all signal s. In this case, (E.47) reads:

$$F_l(\sigma) - q_0 F_h(\sigma) - (1-q_0)(\epsilon_l F_l(\sigma) + \epsilon_h F_h(\sigma)) = \beta \tag{E.48}$$

Imperfect buyers' information reduces the incentives by $(1-q_0)(\epsilon_l F_l + \epsilon_h F_h)$, representing that a signal below σ may lead to reselling an l-asset because of a false positive and to missing the resale of an h-asset because of a false negative. Note that this latter reduction in incentives is identical to an increase in the probability of not receiving bids for h-projects to $q_0 + (1-q_0)\epsilon_h$ from q_0.

Finally, the first-order condition with respect to $r(s)$ is instructive. Denoting by μ the multiplier of the incentive-compatibility constraint and ignoring the feasibility constraint, one obtains:

$$h(s) - r(s) = \frac{\mu}{p} - \frac{\mu + p}{p(1-p)}\phi(s), \tag{E.49}$$

where

$$\phi(s) = \frac{(1-p)\epsilon_l f_l(s)}{p(1-\epsilon_h) f_h(s) + (1-p)\epsilon_l f_l(s)} \tag{E.50}$$

is the probability of a low payoff given a public signal s and a positive buyers' signal. It is decreasing in s, and so the left-hand side is increasing in s.

Note first that if there are only false negatives ($\epsilon_l = 0$) then the reserve price is constant as in the baseline model because $h(s) = h$ and $\phi(s) = 0$. Otherwise, expression (E.50) shows that there are two forces leading to opposite variations of $r(s)$ with respect to s. The right-hand side is increasing in s, reflecting that the rewards for luck from selling an l-project decrease with respect to s. This entails that the marginal discount on a resale $h(s) - r(s)$ should increase in s: Resales are higher-powered incentives for higher signals for which the risk of rewards for luck is lower. On the other hand, $h(s)$ increases in s, so that an increasing marginal discount $h(s) - r(s)$ may still result in an increasing $r(s)$. Noting that

$$h(s) = (1-\phi(s))h + \phi(s)l, \tag{E.51}$$

one can see that $r(s)$ is monotonic. It is increasing if and only if

$$p(1-p)(h-l) \geq \mu + p. \tag{E.52}$$

The following Proposition summarizes this discussion:

Proposition E.2. ***(Imperfectly informed buyers)***

- *If buyers make only false-negative mistakes ($\epsilon_l = 0$), then the model is identical to that with perfectly informed buyers up to an increase in the probability of not receiving bids for h-projects to $q_0 + (1 - q_0)\epsilon_h$ from q_0.*
- *Otherwise, the optimal contract consists in a cut-off σ and a reserve price that is monotonic in s. The distribution of bids is therefore also (stochastically) monotonic in s.*

Proof. Discussion above. ■

E.6. Microfoundations for condition (22)

We interpret the signal s received by a firm as the price fetched by comparable assets sold by other firms. If, as implied by the optimal contract, only h-payoff assets are sold and the principal in a firm is able to relate the project selected by the agent to those sold on the market (there is no misclassification error), actual transactions are perfectly informative and reveal that the agent has selected a high-payoff project. So two routes to noisy market measurement can be taken. The first involves misclassification. The second posits that assets may trade for other reasons than the provision of incentives. We formalize each microfoundation in turn.

We suppose that date-0 private signals are conditionally independent across firms, and so a deterministic fraction p of firms select an h-payoff project in equilibrium. We endogenize firms' date-1 signal using rational expectations equilibrium as our equilibrium concept (see, e.g., Grossman 1981 or Grossman-Stiglitz 1980). Namely, we suppose that all asset resales take place at date 1, but that each firm can condition its own resale decision on the observation of transactions by other firms.[3]

Misclassification

A firm perfectly observes the transaction prices of resold assets (which are from the equilibrium contract only h-payoff assets). It however cannot ascertain perfectly how similar the resold assets are to its own asset. The accuracy of its classification is denoted a and has a differentiable increasing density $g(a)$ over $[0, 1]$ such that $g(0) = 0$ and $g > 0$ over $(0, 1]$.[4] When endowed with an asset of type $k \in \{1; 2\}$, a firm assigns a fraction a of any sample of assets in category k to category

[3] This is similar to REE in Walrasian environments where agents condition their demand schedules on contemporaneous prices.

[4] For example, $g(a) = (1 + \chi)a^{\chi}$ for $\chi > 0$.

k, and misleadingly, a fraction $1-a$ to the other category. The realizations of a are independent across firms, and firms do not observe their own a. A firm's signal s is then the fraction of resold assets to which it assigns the same type as its own asset and has conditional densities:

$$f_h(s) = f_l(1-s) = g\left(s\right), \tag{E.53}$$

and

$$\frac{f_h(s)}{f_l(s)} = \frac{g\left(s\right)}{g\left(1-s\right)} \tag{E.54}$$

is increasing in s because so is g. The distribution of the signal does not depend on λ, and thus condition (22) is satisfied.

Proposition E.3. ***(Misclassification risk)*** *Under misclassification risk, Proposition 10 applies.*

Proof. Discussion above. ■

With such misclassification risk, the signal does not depend on λ and so condition (22) is binding. This implies that imposing a higher degree of conservatism on firms reduces their agency costs only through the channel of a lower cost of resales due to more aggressive bids. The informativeness of market signals is unaffected by an increase in λ. We now develop an alternative microfoundation in which inequality (22) will be strict: An increase in λ will affect both the costs of taking to market and that of marking to market in this case.

Idiosyncratic risk

We now suppose that firms perfectly identify asset types when observing transactions by other firms, but that payoffs across assets of the same type differ along an idiosyncratic component. This corresponds to assets that are heterogenous in nature (over-the-counter derivatives, real estate,...). As mentioned in Section C, this can also stand for changes in an asset fundamental between measurement and disclosure dates. Such idiosyncratic noise per se does not generate noisy inference if only h-payoff assets are resold in equilibrium. So we also add a reason why l-payoff assets are occasionally resold. We describe in turn each ingredient and explain how it affects the equilibrium characterized in Section III.

First, we suppose that the date-2 payoff of each project is equal to $y+z$, where $y \in \{l;h\}$ is identical across projects of the same type. The new terms z are independently and identically distributed across firms with a c.d.f. Ψ that admits a differentiable log-concave density with full support over the real line. We suppose that for all $y \neq 0$, $\Psi(x+y)/\Psi(x)$ spans $(0,+\infty)$ as x spans $\mathbb{R}$.[5] Each firm (principal and agent) and all the buyers who are matched with it (informed or not) observe the realization of z for that firm at date 1, whereas other agents do not.

[5]We could impose positive payoffs at the cost of some additional complexity.

Second, we suppose that in addition to receiving a signal and bids, a firm (principal and agent) privately observes the value of its project's payoff at date 1 with probability $\gamma < \beta$ (so far we had $\gamma = 0$). This affects the provision of incentives to agents as follows. In the event of such an early payoff discovery, the agent receives utility 1 if the payoff is h and 0 if it is l. In the absence of early discovery, the agent is as before rewarded if the signal is above a cut-off σ, or if he successfully resells the asset at a price above $r + z$, where z is the firm's idiosyncratic shock. The pair $\{\sigma, r\}$ solves (3) subject to constraints (4) and (5), with the only change that β is replaced by $\beta' = (\beta - \gamma)/(1 - \gamma) < \beta$ in these equations.

Third, we also assume that a principal, when indifferent between reselling the firm's asset or not, always chooses to do so. This is for expositional simplicity: In the proof of Proposition E.4, we show that such a preference for trading arises endogenously from small gains from trades between principals and potential buyers. This affects equilibrium transactions as follows. We keep assuming an arbitrarily large mass of uninformed buyers, so that each firm always faces competitive uninformed buyers. Firms that discover a l-payoff at date 1 sell their asset to uninformed buyers at the price $l + z$, and do not reward the agent upon such a sale. Whereas l-payoff assets are sold if discovered early by a firm, h-payoff assets are sold only for measurement purposes in the absence of early discovery and when the firm receives a signal below σ and at least one bid above $r + z$. Indeed, indifference between bids implies that informed bids for h-assets are bounded away from h, the principal's valuation of the asset.

Finally, for tractability, we preserve the information structure assumed thus far with signals that are univariate and identically distributed across firms by assuming that each firm observes the price fetched by one asset of the same type as its own one before making its resale decision.[6] This observed transaction price therefore plays the role of the exogenous date-1 signal assumed thus far. We have:

Proposition E.4. ***(Idiosyncratic risk)*** *For κ and l sufficiently small, there exists a stable equilibrium with endogenous signals such that Proposition 10 applies and inequality (22) is strict. This implies that imposing a higher degree of conservatism reduces firms' agency costs by making both marking to market and taking to market strictly more efficient.*

Proof:

Step 1. Optimal contracting in the presence of early payoff discovery

We first revisit the contracting problem of Section I in the case in which, with a probability $\gamma < \beta$, the firm discovers the project value at date 1. It is clearly optimal that, in the event of such an early

[6]Each firm could more generally observe any statistic from a finite sample of transactions.

discovery, the agent receives utility 1 if the payoff is h and 0 if it is l. It is easy to see that the optimal course of action in the absence of early discovery solves the same problem as that in the case $\gamma = 0$ up to a replacement of the parameter β with $\beta' = (\beta - \gamma)/(1 - \gamma) < \beta$.

Step 2. Optimal contracting and bidding in the presence of early payoff discovery

This implies that in the setting of Section III with exogenous signals and endogenous number of informed bidders, Proposition 8 applies in the presence of such early discovery: For κ, l sufficiently small, a stable equilibrium exists and solves (23), (24), and (25) where the parameters β and κ are replaced by $\beta' = (\beta - \gamma)/(1 - \gamma)$ and $\kappa' = \kappa/(1 - \gamma)$ respectively.

Step 3. Optimal contracting and bidding in the presence of early payoff discovery and gains from trade

We now study how the presence of gains from trade between firms' principals and potential buyers affects such a stable equilibrium with possible early discovery described in Steps 1 and 2. We suppose that potential buyers value a payoff $y + z$ at $y + z + \epsilon$, where $\epsilon > 0$. We show that in the limiting case in which $\epsilon \to 0$ (infinitesimal gains from trade), these gains from trade induce the preference for trading that is directly assumed in the above. For ϵ sufficiently small, firms that discover an h-payoff and firms that receive a bid larger than r and a signal larger than σ never sell as their valuation of the project, h, exceeds that of the highest possible bid. This is because the condition that informed buyers be indifferent between bids for h-projects implies that their bids are bounded away from h. Sales that take place above r are therefore only for incentive purposes. Firms that discover an l-payoff always sell as uninformed bids are competitive and thus weakly larger than $l + z + \epsilon$. Firms that do not discover the early payoff but receive a sufficiently low public signal may also sell their project to uninformed buyers, although the signal below which they do so tends to $-\infty$ as $\epsilon \to 0$ because of adverse selection (the firm may be selling because it has discovered an l-payoff). Thus, in the limiting case $\epsilon \to 0$, gains from trade induce only sales of l-payoff projects discovered by firms.

Note that the resales meant to reap gains from trade do not affect informed bidding strategies nor informed bidders' expected profits. Thus the equilibrium values $\{\sigma; r; \lambda\}$ are as stated in Step 2.

Step 4. Endogenous signals

Step 3 shows that there exists a stable equilibrium in the extension of Section III to early payoff discovery and arbitrarily small gains from trade. It remains to show that this applies to the case in which the signals are given by:

$$F_l(s) = \Psi(s - l), \tag{E.55}$$

$$F_h(s, \lambda, r) = \Psi * H_1(s, \lambda, r), \tag{E.56}$$

where Ψ is the c.d.f. of z and

$$H_1(s, \lambda, r) = \sum_{k \geq 1} \frac{q_k(\lambda)}{1 - q_0(\lambda)} S^k(s, \lambda, r), \tag{E.57}$$

where S is implicitly defined by (80). Such F_h, F_l satisfy (22) because $\partial F_l / \partial \lambda = 0$, $\partial F_h / \partial \lambda \leq 0$.

These signals depart from the assumptions of Section III to the extent that F_h also depends on r with $\partial F_h / \partial r \leq 0$. We leave it to the reader to check that the proofs of Propositions 8 and 10 can be simply adapted to this case. ■

Interestingly, this microfoundation is also suggestive of contagion phenomenons. If many firms observe the resale price generated by the same transaction by a firm with an h-project but a negative idiosyncratic shock, then this firm's resale sends low market signals, thereby inducing a large number of ex-post inefficient resales by firms with h-assets.

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